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ELEMENTS

OF

SURVEYING

AND

LEVELING.

BY CHARLES DAVIES, LL.D.,

AUTHOR OF A FULL COURSE OF MATHEMATICS.

REVISED BY

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PREFACE.

DAVIES' Elements of Surveying, first published in 1830, was designed as a text-book for the pupils of the U. S. Military Academy, and in its preparation little regard was had to the supposed wants of other institutions.

The work was, however, received by the public with more favor than was anticipated, and soon became a leading text-book in Colleges, Academies, and the higher grade of Schools. For the purpose of adapting it more fully to the requirements of these institutions, the author made many changes in successive editions, and gave it his final revision in 1870.

In the present edition, while the admirable features which have hitherto commended the work so highly to institutions of learning and to practical surveyors have been retained, some of the topics have been abridged in treatment and some enlarged, others have been added, and the whole has been arranged in the order of progressive development.

It has been the intention to begin with the very elements of the subject and to combine those elements in the simplest manner, so as to render the higher branches of Plane Surveying comparatively easy. The necessary principles of logarithms and plane trigonometry are given, and their mode of application shown. All the instruments needed for plotting have been carefully described; and the uses of those required for the measurement of angles are fully explained.

In the section on Magnetic Declination or Variation of the Needle, papers of the U. S. Coast and Geodetic Survey have been largely used. From them have been taken:—tables of annual changes in declination, and for computing the declination at any epoch, at various places in the United States, which will be found of especial value in re-running lines of old surveys; also, new tables of the times and azimuths of Polaris when at elongation, for use in determining the true meridian with compass or transit, which with the rules given for interpolation are more accurate than any similar tables previously published.

A full account is given of the system adopted in the survey of the public lands; and although the method is simple, it has, nevertheless, been productive of great results, by defining, with mathematical precision, the boundaries of lands in the new States, and thus settling their titles on an indisputable basis. In this connection official instructions and diagrams issued by the U. S. General Land Office have been used, and, as the principal lines of a government survey must be run with reference to the true meridian, the Solar Compass and solar attachment to transit are described.

A change made in the present edition, which must prove particularly acceptable, is the transformation of the article on Mining Surveying into a complete treatise, in which the location of claims on the surface, the latest and best methods of underground traversing, etc., the calculation of ore-reserves, and all that pertains to the work of the Mining Surveyor, are fully explained, and illustrated by practical examples. This improvement is due, substantially, to John G. Murphy, Esq., E.M., at one time Territorial Geologist of Wyoming Territory, an expert Mining Engineer of large and varied practice.

In addition to acknowledgments elsewhere made, the undersigned is indebted to Professor Rodney G. Kimball, of the Brooklyn Polytechnic Institute, for valuable suggestions and labor, and to the Messrs. W. and L. E. Gurley, of Troy, N. Y., for their courtesy in furnishing him, for use, advance sheets of the last edition of their Instrument Manual and many cuts of their surveying instruments.

J. H. VAN AMRINGE,
Editor of DAVIES' COURSE OF MATHEMATICS.

COLUMBIA COLLEGE, N. Y.,
September, 1883.

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BOOK I.

INTRODUCTORY PRINCIPLES AND DEFINITIONS.

SECTION I.

LOGARITHMS.

1. The logarithm of a given number is the *exponent* of the power to which it is necessary to raise a *fixed number* to produce the given number.

The *fixed number* is called **the base of the system.** In the common system, to which alone reference is made in this section, the base is 10. Every number is, therefore, regarded as some power of 10, and the *exponent* of that power is the *logarithm* of the number.

2. If a number is an exact power of 10, its logarithm is a *whole number.* If a number is not an exact power of 10, its logarithm is composed of two parts, a *whole number* called the **Characteristic,** and a *decimal* part called the **Mantissa.** Thus, 225 being greater than 10^2 and less than 10^3, its logarithm is found to be 2.352183, of which 2 is the *characteristic* and .352183 is the *mantissa.*

3. In a table of logarithms, the *mantissas only* are necessarily given. The *characteristic* of the logarithm of a number is determined by one of the two following rules:

RULE I.—*The characteristic of the logarithm of any whole number is positive, and numerically 1 less than the number of places of figures in the given number.*

RULE II.—*The characteristic of the logarithm of a decimal fraction is negative, and numerically 1 greater than the number of 0's that immediately follow the decimal point.*

NOTE 1.—In the logarithm of a decimal fraction, the characteristic alone is negative, the *mantissa being always positive.* This fact is indicated by writing the negative sign over the characteristic: thus, $\bar{2}.371465$, is equivalent to $-2 + .371465$.

NOTE 2.—It is to be observed, that the characteristic of the logarithm of a mixed number is the same as that of its entire part. Thus, the characteristic of the logarithm of 725.4275 is the same as the characteristic of the logarithm of 725.

4. A Table of Logarithms is a table by means of which may be found the logarithm corresponding to any number, or the number corresponding to any logarithm.

In the table appended, the mantissas alone are given; the characteristic may be found by one of the rules of Art. **3**.

The *mantissa* of the logarithm of any number is not changed by multiplying or dividing the number by any *exact* power of 10. Hence, in finding the mantissa of the logarithm of a number, the position of the decimal point may be changed at pleasure. Thus, the *mantissa* of the logarithm of 456357, is the same as that of the number 4563.57; and the mantissa of the logarithm of 75, is the same as that of 7500.

5. To find the logarithm of a number between 1000 and 10,000.—Find the characteristic by the first rule of Art. **3**. To determine the mantissa, find in the column headed "N" the left-hand three figures of the given number; then pass along the horizontal line in which these figures are found, to the column headed by the fourth figure of the given number, and take out the four figures found there; pass back again to the column headed "0," and there will be found in this column, either upon the horizontal line of the first three figures or a few lines above it, a number consisting of six figures, the left-hand two figures of which must be prefixed to the four already taken out. Thus,

$$\text{Log } 8979 = 3.953228.$$

If, however, any *dots* are found at the place of the four figures first taken out, or if in returning to the "0" column any dots are passed, the two figures to be prefixed are the left-hand two of the six figures of the "0" column *immediately below.* Dots in the number taken out must be replaced by zeros. Thus,

$$\text{Log } 3098 = 3.491081$$
$$\text{Log } 2188 = 3.340047$$

6. To find the logarithm of a number between 1 and 1000.— Find the characteristic by the first rule of Art. **3**. To find the mantissa, fill out the given number to four places of figures (or conceive it to be so filled out) by annexing 0's (see Art. **4**), and find the mantissa corresponding to the resulting number, as in Art. **5**. Thus, to find log. of 75: characteristic is 1, by the rule; the mantissa is the same as that corresponding to 7500, *i. e.*, .875061; hence,

$$\text{Log } 75 = 1.875061.$$

In the same way,

$$\text{Log } 2 = 0.301030.$$

7. To find the logarithm of a number greater than 10,000.— Find the characteristic by the first rule of Art. **3**. To find the mantissa: set aside all of the given number except the left-hand four figures, and find the mantissa corresponding to these four, as in Art. **5**; multiply the corresponding *tabular difference*, found in column "D," by the part of the number set aside, and discard as many of the right-hand figures of the product as there are figures in the multiplier, and add the result thus obtained to the mantissa already found. If the left-hand figure of those discarded is 5, or more, increase the number added by 1.

NOTE.—It is to be observed that the *tabular difference*, found in column "D," is **millionths**, and not a whole number; and that, therefore, the result to be added "to the mantissa already found" is **millionths**.

EXAMPLE.—To find the logarithm of 672887: the characteristic is 5; set aside 87, and the mantissa corresponding to 6728 is .827886; the corresponding tabular difference is 65, which multiplied by 87, the part of the number set aside, gives 5655; as there are two figures in the multiplier, discard the right-hand two figures of this product, leaving 56; but as the left-hand figure of those discarded is 5, call the result 57 (which is *millionths*); adding this 57 to the mantissa already found, will give .827943 for the required mantissa; hence,

$$\text{Log } 672887 = 5.827943.$$

In the same way,

$$\text{Log } 3710053 = 6.569380.$$

8. To find the logarithm of a decimal.—Find the characteristic by the second rule of Art. **3**. To find the mantissa, drop the decimal point and consider the decimal a whole number. Find the mantissa of the logarithm of this number as in preceding articles, and it will be the mantissa required. Thus,

$$\text{Log } .0327 = \bar{2}.514548$$
$$\text{Log } .378024 = \bar{1}.577520.$$

NOTE.—To find the logarithm of a *mixed number*, find the characteristic by Note 2, Art. **3**; then drop the decimal point and proceed as above.

9. To find the number corresponding to a given logarithm.—The rule is the reverse of those just given. Look in the table for the mantissa of the given logarithm. If it cannot be found, take out the next less mantissa, and also the corresponding number, which set aside. Find the difference between the mantissa taken out and that of the given logarithm; annex any number of 0's, and divide this result by the corresponding number in the column "D." Annex the quotient to the number set aside, and then, if the characteristic is *positive*, point off, from the left hand, a number of places of figures equal to the characteristic plus 1; the result will be the number required.

If the characteristic is *negative*, prefix to the figures obtained a number of 0's one less than the number of units in the negative characteristic and to the whole prefix a decimal point; the result, a pure decimal, will be the number required.

Example.—Let it be required to find the number corresponding to the logarithm 5.233568.

The next less mantissa in the table is 233504; the corresponding number is 1712, and the tabular difference is 253.

OPERATION.

Given mantissa, ...	233568		
Next less mantissa, ...	233504 . .	1712	
	253) 6400000	(	25296

∴ The required number is 171225.296.

The number corresponding to the logarithm $\bar{2}.233568$ is .0171225+.

10. Multiplication by Logarithms.—Rule.—*Find the logarithms of the factors and take their sum; then find the number corresponding to the resulting logarithm, and it will be the product required.*

Example.—Find the continued product of 3.902, 5971.6, and .0314728.

OPERATION.

$$\begin{array}{lrcl} \log & 3.902 & = & 0.591287 \\ \log & 5971.6 & = & 3.776091 \\ \log & .0314728 & = & \underline{\bar{2}.497936} \\ & & & \underline{2.865314} \quad \therefore \quad 733.354, \text{ product.} \end{array}$$

Here, the 1 carried added to the 3 gives 4, which added to -2 gives 2 as the characteristic of the logarithm of the product.

11. Division by Logarithms.—RULE.—*Find the logarithms of the dividend and divisor, and subtract the latter from the former; then find the number corresponding to the resulting logarithm, and it will be the quotient required.*

EXAMPLES.

1. Divide 24163 by 4567.

OPERATION.

$$\begin{array}{lr} \log 24163 \;.\;.\;.\; & 4.383151 \\ \log 4567 \;.\;.\;.\; & \underline{3.659631} \\ & \underline{0.723520} \quad \therefore \quad 5.29078, \text{ quotient.} \end{array}$$

2. Divide 0.7438 by 12.9476.

OPERATION.

$$\begin{array}{lr} \log 0.7438 \;.\;.\;.\; & \bar{1}.871456 \\ \log 12.9476 \;.\;.\;.\; & \underline{1.112189} \\ & \underline{\bar{2}.759267} \quad \therefore \quad 0.057447, \text{ quotient.} \end{array}$$

Here, 1 taken from $\bar{1}$, gives $\bar{2}$ for a result. The subtraction, as in this case, is always to be performed in the algebraic sense.

The operation of division, particularly when combined with that of multiplication, can often be simplified by using the principle of the

12. Arithmetical Complement.—The *arithmetical complement* of a logarithm is the remainder obtained by subtracting it from 10. Thus, 8.130456 is the arithmetical complement of 1.869544. The arithmetical complement is denoted by the symbol (a. c.).

The following is the rule for the use of the arithmetical complement in division by logarithms:

RULE.—*Find the logarithm of the dividend, and the arithmetical complement of the logarithm of the divisor, add them together, and diminish the sum by 10; the number corresponding to the resulting logarithm will be the quotient required.*

EXAMPLES.—1. Divide 37.149 by 523.76.

	log 37.149 . . .	1.569947	
(a. c.)	log 523.76 . . .	7.280867	
		$\bar{2}.850814$	.·. 0.0709273, quotient.

The operation of subtracting 10 is performed mentally.

2. Find x in the proportion,

$$602.647 : 2.29863 :: x : .037293.$$

	log 602.647 . .	2.780063	
(a. c.)	log 2.29863 . .	9.638531	
	log .037293 . .	$\bar{2}.571627$	
	log x	0.990221	.·. $x = 9.7773+$.

3. Divide the product of 3.58884 and 5672, by the product of 89721 and 42.056.

	log 358884 . . .	5.554954	
	log 5672	3.753736	
(a. c.)	log 89721 . . .	5.047106	
(a. c.)	log 42.056 . . .	8.376182	
		2.731978	.·. 539.48, result.

20 is here subtracted, as (a. c.) has been twice used.

NOTE.—If the logarithm, whose arithmetical complement is taken, exceeds 10, subtract it from 20, and reject 20 in the final operation.

13. Raising to Powers by Logarithms.—RULE.—*Find the logarithm of the number, and multiply it by the exponent of the power; then find the number corresponding to the resulting logarithm, and it will be the power required.*

EXAMPLE.—Find the 5th power of 9.

$$\begin{array}{lr} \log 9 \; . \; . \; . \; . \; . & 0.954243 \\ & \underline{5} \\ & \underline{4.771215} \quad \therefore \quad 59049, \text{ power.} \end{array}$$

14. Extracting Roots by Logarithms.—RULE.—*Find the logarithm of the number and divide it by the index of the root; then find the number corresponding to the resulting logarithm, and it will be the root required.*

EXAMPLE.—Find the cube root of 4096.

The logarithm of 4096 is 3.612360, and one-third of this is 1.204120. The corresponding number is 16, which is the root sought.

If the characteristic of the logarithm of the given number is *negative* and not *exactly* divisible by the index of the root, add to it such *negative* quantity as shall make it exactly divisible, and add also to the mantissa a numerically equal *positive* quantity.

Thus, let the square root of .00863 be required.

$$\log .00863 = \bar{3}.936011 = \bar{4} + 1.936011.$$

$$\log \sqrt{.00863} = \frac{\bar{4} + 1.936011}{2} = \bar{2}.968006.$$

The number sought is therefore .09289+.

SECTION II.

PLANE TRIGONOMETRY.

15. Plane Trigonometry is that branch of Mathematics which treats of the *solution* of plane triangles.

In every plane triangle there are six parts: *three sides* and *three angles*. When three of these parts are given, one being a side, the remaining parts may be found by computation. The operation of finding the unknown parts, is called the *solution* of the triangle.

16. A plane angle is measured by the arc of a circle included between its sides, the centre of the circle being at the vertex, and its radius being equal to 1.

Thus, if the vertex A be taken as a centre, and the radius AB be equal to 1, the intercepted arc BC will measure the angle A.

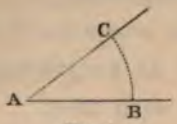


FIG. 1.

Let $ABCD$ represent a circle whose radius is equal to 1, and AC, BD, two diameters perpendicular to each other. These diameters divide the circumference into four equal parts, called *quadrants;* and because each of the angles at the centre is a right angle, it follows that a *right angle* is measured by a *quadrant*. An *acute angle* is measured by *an arc less than a quadrant*, and an *obtuse angle*, by *an arc greater than a quadrant*.

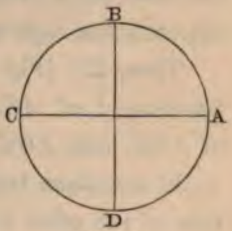


FIG. 2.

17. In Geometry, the unit of angular measure is a *right angle;* so in Trigonometry, *the primary unit is a quadrant*, which is the measure of a right angle.

For convenience, the quadrant is divided into 90 equal parts, each of which is called *a degree;* each degree into 60 equal parts, called *minutes;* and each minute into 60 equal parts, called *seconds.* Degrees, minutes, and seconds, are denoted by the symbols °, ′, ″. Thus, the expression 7° 22′ 33″, is read, *7 degrees,* 22 *minutes,* and 33 *seconds.* Fractional parts of a second are expressed decimally.

18. The *complement of an arc* is the difference between that arc and 90°. The *complement of an angle* is the difference between that angle and a right angle.

Thus, *EB* is the complement of *AE,* and *FB* is the complement of *AF.* In like manner, *EOB* is the complement of *AOE,* and *FOB* is the complement of *AOF.*

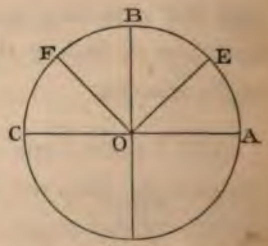


FIG 3

In a right-angled triangle, the acute angles are complements of each other.

19. The *supplement of an arc* is the difference between that arc and 180°. The *supplement of an angle* is the difference between that angle and two right angles.

Thus, *EC* (Fig. 3) is the supplement of *AE,* and *FC* the supplement of *AF.* In like manner, *EOC* is the supplement of *AOE,* and *FOC* the supplement of *AOF.*

In any plane triangle, either angle is the supplement of the sum of the other two.

20. Instead of the arcs themselves, certain *functions* of the arcs, as explained below, are used. A *function* of a quantity is something which depends upon that quantity for its value.

The following functions are the only ones needed for solving triangles:

21. The *sine* of an arc is the distance of one extremity of the arc from the diameter through the other extremity.

Thus, PM (Fig. 4) is the sine of AM, and $P'M'$ is the sine of AM'.

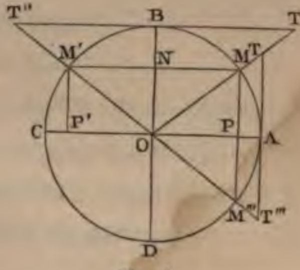


FIG. 4.

22. The *cosine* of an arc is the sine of the complement of the arc, "complement sine" being contracted into cosine.

Thus, NM (Fig. 4) is the cosine of AM, and NM' is the cosine of AM'. These lines are respectively equal to OP and OP'.

23. The *tangent* of an arc is the perpendicular to the radius at one extremity of the arc, limited by the prolongation of the diameter through the other extremity.

Thus, AT (Fig. 4) is the tangent of the arc AM, and AT''' is the tangent of the arc AM'.

24. The *cotangent* of an arc is the tangent of its complement, "complement tangent" being contracted into cotangent.

Thus, BT'' (Fig. 4) is the cotangent of the arc AM, and BT''' is the cotangent of the arc AM'.

The sine, cosine, tangent, and cotangent of an arc, a, are, for convenience, written sin a, cos a, tan a, and cot a.

These functions of an arc may also be considered as functions of the angle which the arc measures.

Thus, (Fig. 4) PM, NM, AT, and BT', are respectively the sine, cosine, tangent, and cotangent of the angle AOM, as well as of the arc AM.

25. The sine of an arc is equal to the sine of its supplement; and, in general, any function of an arc is equal to the corresponding function of its supplement. Thus, if A is any arc or angle,

$$\begin{aligned} \sin A &= \sin (180^\circ - A); \\ \cos A &= \cos (180^\circ - A); \\ \tan A &= \tan (180^\circ - A); \\ \cot A &= \cot (180^\circ - A). \end{aligned}$$

NOTE.—These relations exist between the *numerical values* of the functions; the *algebraic signs*, which they have in the different quadrants, are not considered.

26. A Natural Sine, Cosine, Tangent, or Cotangent, is the sine, cosine, tangent, or cotangent, of an arc whose radius is 1.

A Table of Natural Sines is a table from which the natural sine, cosine, tangent, or cotangent of any arc may be found.

The Table of Natural Sines, beginning at page 63 of the tables, gives the values of the sines and cosines only. If the tangent or cotangent of an arc, A, is desired, it may be found by the relation,

$$\tan A = \frac{\sin A}{\cos A}; \qquad \cot A = \frac{\cos A}{\sin A}.$$

TABLE OF LOGARITHMIC SINES.

27. A Logarithmic Sine, Cosine, Tangent, or Cotangent is the *logarithm* of the sine, cosine, tangent, or cotangent of an arc whose radius is 10,000,000,000.

A Table of Logarithmic Sines and Tangents is a table giving the logarithm of the sine and cosine, tangent and cotangent of any arc or angle.

The logarithm of the tabular radius is 10.

Any *logarithmic* function of an arc or angle may be found by multiplying the corresponding *natural* function by 10,000,000,000, and then taking the logarithm of the result; or more simply, by taking the logarithm of the corresponding *natural* function, and then adding 10 to the result.

28. In the table, beginning at page 18 of the tables, the logarithmic functions are given for every *minute* from 0° to 90°. In addition, their rates of change for each *second*, are given in the column headed "D."

For the sine and cosine, there are separate columns of differences, which are written to the right of the respective columns; but for the tangent and cotangent, there is but a single column of differences, which is written between them.

The angle obtained by taking the degrees from the *top* of the page, and the minutes from any line on the *left* hand of the page, is the *complement* of that obtained by taking the degrees from the *bottom* of the page, and the minutes from the same line on the *right* hand of the page. But, by definition, the cosine and the cotangent of an arc are, respectively, the sine and the tangent of the complement of that arc (Arts. **22** and **24**); hence, the columns designated *sine* and *tang*, at the top of the page, are designated *cosine* and *cotang* at the bottom.

29. To find the logarithmic functions of an angle which is expressed in degrees and minutes.

If the angle is *less* than 45°, look for the degrees at the *top* of the page, and the minutes in the *left* hand column; then follow the corresponding horizontal line to the column designated at the *top* by *sine, cosine, tang*, or *cotang*, as the case may be; the number there found is the logarithm required. Thus,

log sin 19° 55′ 9.532312
log tan 19° 55′ 9.559097

If the angle is *greater* than 45°, look for the degrees at the *bottom* of the page, and for the minutes in the *right* hand column; then follow the corresponding horizontal line backwards to the colnmn designated at the *bottom* by *sine*, *cosine*, *tang*, or *cotang*, as the case may be; the number there found is the logarithm required. Thus,

log cos 52° 18′ 9.786416
log tan 52° 18′ 10.111884

30. To find the logarithmic functions of an angle which is expressed in degrees, minutes, and seconds.

Find the logarithm corresponding to the degrees and minutes as before; then multiply the corresponding number taken from the column headed "D" (which is *millionths*), by the number of seconds, and add the product to the preceding result, for the sine or tangent, and subtract it therefrom for the cosine or cotangent.

EXAMPLES.

1. Find the logarithmic sine of 40° 26′ 26″.

OPERATION.

log sin 40° 26′			9.811952
Tabular difference	2.47		
No. of seconds .	28		
Product	69.16	to be added .	69
log sin 40° 26′ 28″			9.812021

The same rule is followed for the figures discarded (in this case 16), as in Art. **7**.

2. Find the logarithmic cosine of 53° 40′ 46″.

OPERATION.

log cos 53° 40′			9.772675
Tabular difference	2.86		
No. of seconds .	46		
Product . . .	131.56	to be subtracted	132
log cos 53° 40′ 46″			9.772543

If the angle is greater than 90°, we find the required function of its supplement (Art. **25**).

3. Find the logarithmic tangent of 118° 18′ 25″.

OPERATION.

	180°		
Given arc	118° 18′ 25″		
Supplement	61° 41′ 35″		
log tan 61° 41′			10.268556
Tabular difference	5.04		
No. of seconds .	35		
Product . . .	176.40	to be added .	176
log tan 118° 18′ 25″			10.268732

31. To find the angle corresponding to any logarithmic function.

This is done by reversing the preceding rule: Look in the proper column of the table for the given logarithm; if it is found there, the degrees are to be taken from the top or bottom, and the minutes from the left or right hand column, as the case may be. If the given logarithm is not found in the table, then find the next less logarithm, and take from the table the corresponding degrees and minutes, and set them aside. Subtract the logarithm found in the table, from the given logarithm, two 0's to the remainder, and divide this result by the corresponding tabular difference. The quotient will be seconds, which must be *added* to the degrees and minutes set aside, in the case of a sine or tangent, and *subtracted*, in the case of a cosine or a cotangent.

EXAMPLES.

1. Find the angle corresponding to the logarithmic sine 9.422248.

OPERATION.

Given logarithm . . . 9.422248
Next less in table . . . 9.421857 . . . 15° 19′
Tabular difference 7.68) 391.00 (51″, to be added.
Hence, the required arc is 15° 19′ 51″.

2. Find the angle corresponding to the logarithmic cosine 9.427485.

OPERATION.

Given logarithm . . . 9.427485
Next less in table . . . 9.427354 . . . 74° 29′
Tabular difference 7.58) 131.00 (17″, to be subt.
Hence, the required angle is 74° 28′ 43″.

32. Theorem I.—*The sides of a plane triangle are proportional to the sines of their opposite angles.*

In the triangle ABC let the large letters A, B, C, designate the angles, and the corresponding small letters, a, b, c, the sides opposite; then,

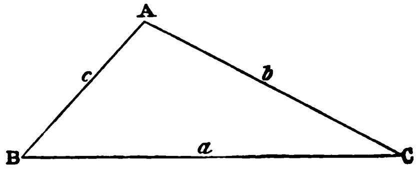


FIG. 5.

$$a : b :: \sin A : \sin B;$$
$$a : c :: \sin A : \sin C;$$
$$b : c :: \sin B : \sin C.$$

33. Theorem II.—*In any plane triangle, the sum of the two sides containing any angle, is to their difference, as the tangent of half the sum of the two other angles is to the tangent of half their difference.*

Thus, in the triangle ABC (Fig. 5),

$$a+b : a-b :: \tan\tfrac{1}{2}(A+B) : \tan\tfrac{1}{2}(A-B);$$
$$a+c : a-c :: \tan\tfrac{1}{2}(A+C) : \tan\tfrac{1}{2}(A-C);$$
$$b+c : b-c :: \tan\tfrac{1}{2}(B+C) : \tan\tfrac{1}{2}(B-C).$$

By solving any one of the above proportions, the first three terms being known, the *tangent* of half the difference of the two unknown angles is obtained, and from this tangent the half difference itself is found. The greater of the two unknown angles is equal to half their sum added to half their difference; the smaller is equal to half their sum diminished by half their difference.

34. Theorem III.—*In any plane triangle, if a line is drawn from the vertex of the vertical angle perpendicular to the base, dividing it into two segments: then, the sum of the two segments, or the whole base, is to the sum of the two other sides, as the difference of those sides, to the difference of the segments.*

Thus, in the triangle ABC (Fig. 6),

$$s+s' : b+c :: b-c : s-s'.$$

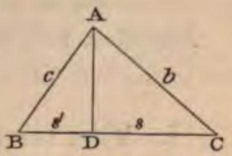


Fig. 6.

35. Theorem IV.—*In any right-angled plane triangle, radius is to the tangent of either of the acute angles, as the side adjacent to the side opposite.*

Let CAB (Fig. 7) be the proposed triangle, and denote the radius by R: then will

R[*] : tan C :: AC, or b : AB, or c;

Also,

R[*] : tan B :: AB, or c : AC, or b.

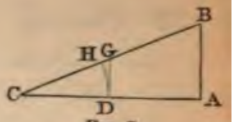


FIG. 7.

36. Theorem V.—*In any right-angled triangle, radius is to the cosine of either of the acute angles, as the hypothenuse to the side adjacent.*

In the triangle CAB (Fig. 7),

R[*] : cos C :: BC, or a : AC, or b;

Also,

R[*] : cos B :: BC, or a : AB, or c.

37. Solution of Triangles.—The relations between the sides and angles of plane triangles, stated in these five theorems, are sufficient to solve all the cases of Plane Trigonometry. Of the six parts, which make up a plane triangle, three must be given, and at least one of these must be a side, before the others can be determined.

If the three angles only are given, it is plain that an indefinite number of similar triangles may be constructed, the angles of which may be respectively equal to the angles that are given and, therefore, the sides could not be determined.

Assuming, with this restriction, any three parts of a triangle, one of the four following cases will always be presented:

I. When two angles and a side are given.

II. When two sides and an angle opposite one of them are given.

III. When two sides and the included angle are given.

IV. When the three sides are given.

---

[*] If *logarithmic* functions are used, R is equal to 10,000,000,000, and its logarithm is 10; otherwise, R is equal to 1.

CASE I.

38. When two angles and a side are given.

In a plane triangle, ABC, there are given the angle $A = 58° \; 07'$, the angle $B = 22° \; 37'$, and the side AB, or $c = 408$ yards; to find C, a, and b. (The sides lying opposite the angles A, B, and C, are denoted by a, b, and c.

Add the given angles, A and B, together, and subtract their sum from 180°; the remainder will be the other angle, C. Then from the proportion (Theorem I),

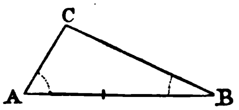


FIG. 8.

$$\sin C : \sin A :: c : a; \quad a \text{ may be found};$$

and from the proportion,

$$\sin C : \sin B :: c : b; \quad b \text{ may be found.}$$

CASE II.

39. When two sides and an angle opposite one of them are given.

In a plane triangle, ABC, there are given AC, or $b = 216$, CB, or $a = 117$, the angle $A = 22° \; 37'$, to find the other parts.

GEOMETRICALLY.

Draw an indefinite right line $AB'B$; from any point, as A, draw AC, making $BAC = 22° \; 37'$ and make $AC = 216$. With C as a centre, and a radius equal to 117, the other given side, describe the arc $B'B$; draw CB and CB'; then will either of the triangles, ACB or ACB', answer all the conditions of the question.

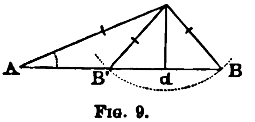


FIG. 9.

TRIGONOMETRICALLY.

From Theorem I, we have,

$$a : b :: \sin A : \sin B.$$

By applying logarithms, we have,

(a. c.) log a (117)	7.931814
log b (216)	2.334454
log sin A (22° 37′)	9.584968
log sin B, 45° 13′ 55″, or 134° 46′ 05″	9.851236

The ambiguity in this and similar examples, arises in consequence of the first proportion being true for either of the angles ABC, or $AB'C$, which are supplements of each other and, therefore, have the same sine (Art. **25**). So long as the two triangles ACB and ACB' exist, the ambiguity will continue. But if the side CB, opposite the given angle, is greater than AC, the arc BB', described from C as a centre and with a radius equal to the side a, will cut the line ABB', on the same side of the point A, in but *one* point, and then there will be only one triangle answering to the conditions.

If the side CB is equal to the perpendicular Cd, the arc BB' will be tangent to ABB', and in this case also, there will be but one triangle. When CB is less than the perpendicular Cd, the arc BB' will not intersect the base ABB', and in that case no triangle can be formed, or it will be impossible to fulfill the conditions of the problem.

In the example under consideration, there are two solutions, the first corresponding to $B = 45°\ 13'\ 55''$, and the second to $AB'C = 134°\ 46'\ 05''$.

FIRST CASE.

A	22° 37′
B	45° 13′ 55″
C	180—67° 50′ 55″ = 112° 09′ 05″.

Then, in the triangle ACB,

$$\sin B : \sin C :: b : c,$$

and applying logarithms,

$$\begin{array}{lll}
\text{(a. c)} & \log \sin B\ (45^\circ\ 13'\ 55'') \ldots\ldots & 0.148764 \\
 & \log \sin C\ (112^\circ\ 09'\ 05'') \ldots\ldots & 9.966700 \\
 & \log b\ (216) \ldots\ldots\ldots\ldots & \underline{2.334454} \\
 & \log c\ 281.785 \ldots\ldots\ldots\ldots & \underline{2.449918}
\end{array}$$

SECOND CASE.

$$\begin{array}{lll}
A \ldots\ldots\ldots\ldots & & 22^\circ\ 37' \\
B \ldots\ldots\ldots\ldots & & \underline{134^\circ\ 46'\ 05''} \\
C' \ldots\ldots\ldots & 180^\circ - & \underline{157^\circ\ 23'\ 05''} = 22^\circ\ 36'\ 55''.
\end{array}$$

Then, in the triangle $AC'B'$,

$$\sin B' : \sin C' : b : c',$$

and applying logarithms,

$$\begin{array}{lll}
\text{(a. c.)} & \log \sin B\ (134^\circ\ 46'\ 05'') \ldots\ldots & 0.148764 \\
 & \log \sin C'\ (22^\circ\ 36'\ 55'') \ldots\ldots & 9.584943 \\
 & \log b\ (216) \ldots\ldots\ldots\ldots & \underline{2.334454} \\
 & \log c'\ 116.993 \ldots\ldots\ldots\ldots & \underline{2.068161}
\end{array}$$

2. Given two sides of a triangle, 50 and 40 respectively, and the angle opposite the latter, equal to 32°; required the remaining parts of the triangle.

Ans. If the angle opposite the side 50 is acute, it is equal to 41° 28′ 59″; the third angle is then equal to 106° 31′ 01″, and the third side to 72.368. If the angle opposite the side 50 is obtuse, it is equal to 138° 31′ 01″, the third angle to 9° 28′ 59″, and the remaining side to 12.436.

CASE III.

40. When two sides and their included angle are given.

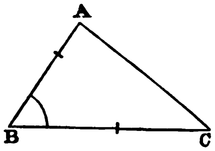


FIG. 10.

Let ABC be a triangle; AB and BC, the given sides, and B the given angle.

Since B is known, we can find the sum of the two other angles; for,

$$A+C = 180^\circ - B,$$

and

$$\tfrac{1}{2}(A+C) = \tfrac{1}{2}(180^\circ - B).$$

We next find half the difference of the angles A and C, by Theorem II, viz.,

$$BC+BA : BC-BA :: \tan\tfrac{1}{2}(A+C) : \tan\tfrac{1}{2}(A-C),$$

in which we consider BC greater than BA, and therefore A is greater than C; since the greater angle must be opposite the greater side.

Having found half the difference of A and C, by adding it to the half sum, $\tfrac{1}{2}(A+C)$, we obtain the greater angle, and by subtracting it from half the sum, we obtain the less. That is,

$$\tfrac{1}{2}(A+C)+\tfrac{1}{2}(A-C) = A,$$

and

$$\tfrac{1}{2}(A+C)-\tfrac{1}{2}(A-C) = C.$$

Having found the angles A and C, the third side AC may be found by the proportion,

$$\sin A : \sin B :: a : b.$$

CASE IV.

41. Having given the three sides of a plane triangle to find the angles.

Let fall a perpendicular from the angle opposite the greatest side, dividing the given triangle into two right-angled triangles; then find the difference of the segments of the base by Theorem III. Half this difference being added to half the base, gives the greater segment; and, being subtracted from half the base, gives the less segment; the greater segment belongs to the right-angled triangle having the greater hypothenuse. We then have two sides and the right angle of each of two right-angled triangles, to find the acute angles.

EXAMPLE.—The sides of a plane triangle being given; viz., $BC = 40$, $AC = 34$, and $AB = 25$; required the angles.

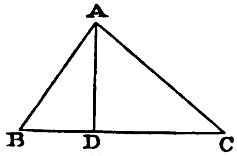


FIG. 11.

$$BC : AC + AB :: AC - AB : CD - BD.$$

That is, $40 : 59 :: 9 : \frac{59 \times 9}{40} = 13.275.$

Then, $\frac{40 + 13.275}{2} = 26.6375 = CD.$

And, $\frac{40 + 13.275}{2} = 13.3625 = BD.$

In the triangle DAC, to find the angle DAC.

$$AC : DC :: \sin D : \sin DAC.$$

Applying logarithms, we have,

(a. c.) log AC (34)	8.468521
log DC (26.6375)	1.425493
log sin D (90°)	10.000000
log sin DAC 51° 34′ 40″ . . .	9.894014

In the triangle BAD, to find the angle BAD.

$$AB : BD :: \sin D : \sin BAD.$$

Applying logarithms, we have,

(a. c.) log AB (25) 8.602060
log BD (13.3625) 1.125887
log sin D (90°) 10.000000
log sin BAD 32° 18′ 35″ . . . 9.727947

$$\text{Hence,}\quad 90^\circ - DAC = 90^\circ - 51^\circ\ 34'\ 40'' = 38^\circ\ 25'\ 20'' = C,$$

$$\text{and,}\quad 90^\circ - BAD = 90^\circ - 32^\circ\ 18'\ 35'' = 57^\circ\ 41'\ 25'' = B,$$

$$\text{and,}\quad BAD + DAC = 51^\circ\ 34'\ 40'' + 32^\circ\ 18'\ 35''$$
$$= 83^\circ\ 53'\ 15'' = A.$$

42. Solution of Right-angled Triangles.—The unknown parts of a right-angled triangle may be found by one of the last four cases; or, if two of the sides are given, by means of the property that the square of the hypothenuse is equal to the sum of the squares of the two other sides. Or, the parts may be found by Theorems IV. and V.

EXAMPLES.

1. In a right-angled triangle BAC, there are given the hypothenuse $BC = 250$, and the base $AC = 240$; required the other parts.

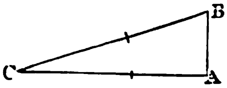


FIG. 12.

Ans. $B = 73^\circ\ 44'\ 23''$; $C = 16^\circ\ 15'\ 37''$; $AB = 70$.

2. In a right-angled triangle BAC, there are given,

$$AC = 384, \text{ and } B = 53^\circ\ 08';$$

required the remaining parts.

Ans. $AB = 287.96$; $BC = 479.979$; $C = 36^\circ\ 52'$.

SECTION III.

INSTRUMENTS FOR PLOTTING.

43. The ordinary implements for making a diagram or plot of a survey are—drawing board ; T-square ; dividers ; ruler and triangle ; scale of equal parts ; semicircular protractor.

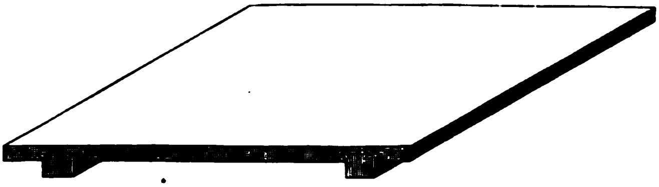


FIG. 13.

44. **A Drawing Board** (Fig. 13) is a rectangular board of about 24 by 30 inches, ¾ths of an inch thick, made of several pieces of well seasoned white pine, fitted together with the grain running in different directions to prevent warping. It is important that its angles should be perfect right angles.

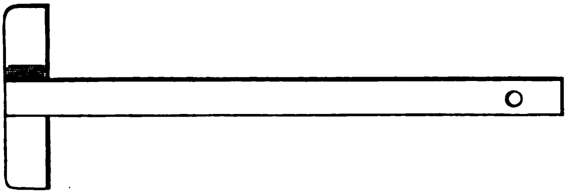


FIG. 14.

45. **A T-square** (Fig. 14) is a ruler about 2 feet in length let into a thicker piece of wood at right angles to it. One side of the cross-piece is even with the ruler and the other side projects somewhat, giving a shoulder on that side. It is a convenient instrument for drawing parallels and perpendiculars.

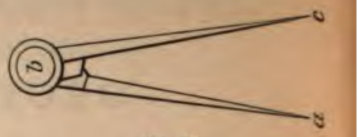


Fig. 15.

46. The Dividers (Fig. 15) consists of two legs *ba*, *bc*, which may be easily turned around a joint at *b*.

One of the principal uses of this instrument is to lay off on a line, a distance equal to a given line.

For example, to lay off on CD, a distance equal to AB.

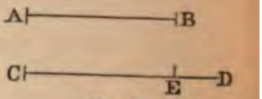


Fig. 16.

Open the points of the dividers to a greater distance than *AB*, place one point *lightly* upon *A*, and then slowly and *continuously* close them till the point reaches *B*. Then raise the dividers, place one foot at *C*, and mark with the other the distance *CE*: this will evidently be equal to *AB*.

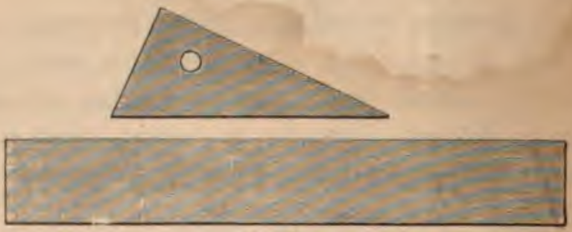


Fig. 17.

47. Ruler and Triangle.—A Ruler of convenient size is about twenty inches in length, two inches wide, and a fifth of an inch in thickness. It should be made of a hard material, perfectly straight and smooth.

The hypothenuse of the right-angled triangle, which is used in connection with it, should be about ten inches in length, and it is most convenient to have one of the sides considerably longer than the other.

The two following problems may be solved with the ruler and triangle.

I. To draw through a given point a line which shall be parallel to a given line.

48. Let *C* be the given point, and *AB* the given line.

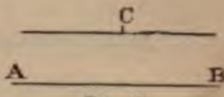


FIG. 18.

Place the hypothenuse of the triangle against the edge of the ruler, and then place the ruler and triangle on the paper, so that one of the sides of the triangle shall coincide exactly with *AB*; the triangle being below the line.

Then, placing the thumb and fingers of the left hand firmly on the ruler, slide the triangle, with the other hand, along the ruler, until the side which coincided with *AB* reaches the point *C*. Extend the first and second fingers of the left hand upon the triangle to hold it firmly in place, the thumb and remaining fingers steadying the ruler, and with the right hand, mark with a pen or pencil, a line through *C*: this line will be parallel to *AB*.

II. To draw through a given point a line which shall be perpendicular to a given line.

49. Let *AB* be the given line, and *D* the given point.

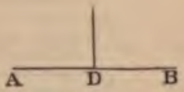


FIG. 19.

Place the hypothenuse of the triangle against the edge of the ruler, as before. Then place the ruler and triangle so that one of the sides of the triangle shall coincide exactly with the line *AB*. Then slide the triangle along the ruler until the other side reaches the point *D*: then, draw through *D*, a right line, and it will be perpendicular to *AB*.

The right angle of the triangle should be carefully tested by laying off a perpendicular through the same given point;

with the triangle in two positions—to the right of the perpendicular, and then to the left of it.

50. A Scale of Equal Parts (Fig. 20) is formed by dividing a line of a given length, into equal portions.

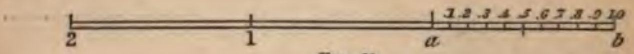


FIG. 20.

If, for example, the line *ab*, of a given length, say one inch, be divided into any number of equal parts, as 10, the scale thus formed is called a scale of *ten parts to the inch.* The line *ab*, which is divided, is called the *unit of the scale.* This unit is laid off several times on the left of the divided line, and the points marked 1, 2, 3, &c.

The unit of scales of equal parts is, in general, either an inch, or an exact part of an inch. If, for example, *ab*, the unit of the scale, were half an inch, the scale would be one of 10 parts to half an inch, or of 20 parts to the inch.

If it were required to take from the scale a line equal to two inches and six-tenths, place one foot of the dividers at 2, on the left, and close the other to .6, which marks the sixth of the small divisions: the dividers will then embrace the required distance.

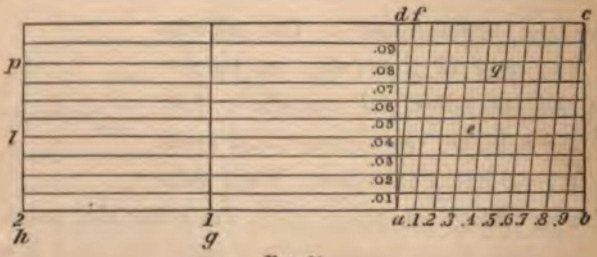


FIG. 21.

51. A Diagonal Scale of Equal Parts (Fig. 21) is thus constructed. Take *ab* for the unit of the scale, which may be one inch. ½, ¼, or ¾ of an inch, in length. On *ab* describe the square *abcd*. Divide the sides *ab* and *dc* each into ten equal parts. Draw *af*, and the other nine parallels as in the figure.

Produce *ba*, to the left, and lay off the unit of the scale any convenient number of times, and mark the points 1, 2, 3, &c. Then, divide the line *ad* into ten equal parts, and through the points of division draw parallels to *ab*, as in the figure.

Now, the small divisions of the line *ab* are each one-tenth (.1) of *ab* ; they are therefore .1 of *ad*, or .1 of *ag* or *gh*.

If we consider the triangle *adf*, we see, that the base *df* is one-tenth of *ad*, the unit of the scale. Since the distance from *a* to the first horizontal line above *ab* is one-tenth of the distance *ad*, it follows that the distance measured on that line, between *ad* and *af*, is one-tenth of *df* : but since one-tenth of a tenth is a hundredth, it follows that this distance is one hundredth (.01) of the unit of the scale. A like distance, measured on the second line, is two hundredths (.02) of the unit of the scale ; on the third, .03 ; on the fourth, .04, &c.

If it were required to take, in the dividers, the unit of the scale, and any number of tenths, place one foot of the dividers at 1, and close the other to that figure between *a* and *b* which designates the tenths. If two or more units are required, the dividers must be placed on a point of division further to the left.

When units, tenths, and hundredths are required, place one foot of the dividers where the vertical line through the point which designates the units, intersects the line which designates the hundredths : then, close the dividers to that line between *ad* and *bc* which designates the tenths : the distance so embraced will be the one required.

For example, to take off the distance 2.34, we place one foot of the dividers at *l*, and close the other to *e* : and to take distance 1.36, we place one foot of the dividers at *p* and close the other at *t*.

NOTE 1.—If a line is so long that the whole of it cannot be taken from the scale, it must be divided, and the parts of it taken from the scale in succession.

NOTE 2.—If a line be given upon the paper, its length can be found by taking it in the dividers and applying it to the scale.

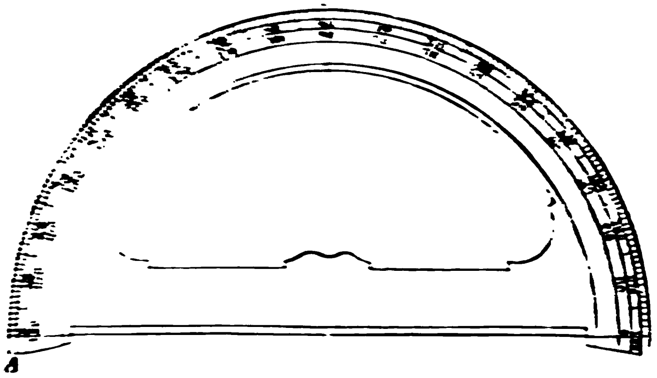


Fig. 22.

52. A Semicircular Protractor (Fig. 22) is used to lay down, or protract angles. It may also be used to measure angles included between lines already drawn upon paper.

It consists of a brass semicircle, *ABC*, divided to half degrees. The degrees are numbered from 0 to 180, both ways; that is, from *A* to *B* and from *B* to *A*. The divisions, in the figure, are made only to degrees. There is a small notch at the middle of the diameter *AB*, which indicates the centre of the protractor.

To lay off an angle with a Protractor.

53. Place the diameter AB on the line, so that the centre shall fall on the angular point. Then count the degrees contained in the given angle, from A toward B, or from B toward A, and mark the extremity of the arc with a pin. Remove the protractor, and draw a line through the point so marked, and the angular point: this line will make with the given line the required angle.

The ordinary brass or horn protractors are of but little value. *Printed* protractors of six and twelve inches diameter, upon heavy paper, or bristol board, and divided to quarter degrees, are very useful and reliable.

By the following method an angle may be laid off with even greater accuracy than with a protractor. With a reliable scale of inches, divided to hundredths, set the dividers at *five* inches, and placing one point at the given vertex A (Fig. 23), describe the arc BC; take out from the table the natural sine of *half* the given angle, multiply it by 10, and call the product inches; with the dividers take off this number of inches from the scale, and placing one point at B, describe an arc cutting BC at C; CAB will be the required angle.

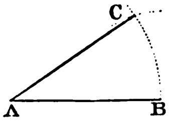


FIG. 23.

It is evident that twice the sine of half the angle is the chord of the whole angle; and since the radius used is 5 inches, we have

$$2\,(\text{Nat. sine } \tfrac{1}{2}a \times 5) = 10 \times \text{Nat. sine } \tfrac{1}{2}a.$$

SECTION IV.

DEFINITIONS.

54. Surveying comprises all the operations necessary for finding the lengths and directions of the bounding lines of any portion of the earth's surface, the area of such portion, and for making on paper an accurate delineation, or map, of the surface and the boundaries.

55. Plane Surveying is that branch of surveying in which the curvature of the earth is neglected, as it may be when the survey is limited to small portions of the surface.

56. Geodesy, or **Geodetic Surveying,** is that branch in which the curvature of the earth is taken into account, as it must be in all extensive surveys.

57. A **Horizontal Plane** at any point is a plane perpendicular to the radius of the earth drawn to that point.

58. A **Vertical Plane** is a plane perpendicular to a horizontal plane.

59. A **Horizontal Line** is any line of a horizontal plane.

60. A **Vertical Line** is a line perpendicular to a horizontal plane.

61. An **Oblique Line** is a line inclined; *i. e.*, neither parallel nor perpendicular to a horizontal plane.

Thus (Fig. 24), AB and DC are horizontal lines; BC and AD are vertical lines; and AC and BD are oblique lines.

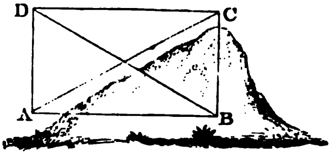


FIG. 24.

62. The Horizontal Distance between two points is the horizontal line intercepted between the two vertical lines passing through those points. Thus, *DC* or *AB* (Fig. 24), is the horizontal distance between the two points *A* and *C*, or between the points *B* and *D*.

63. A Horizontal Angle is an angle whose sides are horizontal; the plane of its sides is also horizontal.

64. A Vertical Angle is an angle the plane of whose sides is vertical.

65. An Angle of Elevation is a vertical angle having one of its sides horizontal and the other oblique, the oblique side being *above* the horizontal side. Thus, *BAC* (Fig. 24) is the angle of elevation from *A* to *C*.

66. An Angle of Depression is a vertical angle having one of its sides horizontal and the other oblique, the oblique side being *below* the horizontal side. Thus, *DCA* (Fig. 24) is the angle of depression from *C* to *A*.

67. An Oblique Angle is an angle the plane of whose sides is inclined to a horizontal plane.

BOOK II.

CHAIN SURVEYING.

SECTION I.

MEASUREMENT OF DISTANCES.

68. Any tape, rod, or chain, divided into equal parts, may be used as a measure for finding the distance between two points.

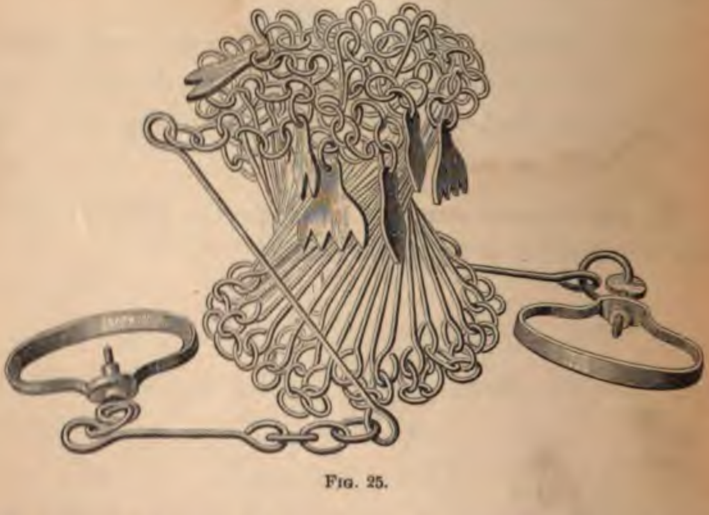


FIG. 25.

The measure in general use for land surveying is a chain of four rods, or sixty-six feet in length, called Gunter's chain (Fig. 25), from the name of the inventor. It is composed of 100 links, each joined to the other by two or three rings. Every tenth link from either end, is marked by a small attached brass pendant or tag, which is notched to designate its number from the end. The tag at the middle, or fifty-link, point is distinguished by being rounded, or by some other peculiarity of make. As the tags at equal distances from the two ends of the chain are marked the same, care must be taken not to mistake forty links for sixty, &c., and the reverse. To avoid such error, it would be better to have the tags marked in regular order from the beginning to the end of the chain, rather than from both ends to the middle.

A link in measure includes a *bar*, with its connecting ring at each end; when there are three connecting rings, a ring and a half at each end is included.

The handles are of brass, and each forms part of the end link, to which it is connected by a nut, by which also the length of the chain is adjusted.

To determine whether to measure from the *inside* of the brass handle, or from the *outside*, double back the last two or three links upon the preceding links and compare.

The division of the chain into 100 equal parts is very convenient, since the divisions, or links, are decimals of the whole chain, and in the calculations are treated as such.

TABLE.

1 chain = 4 rods = 66 feet = 792 inches = 100 links.
1 link = 7.92 inches.
80 chains = 320 rods = 5280 feet = 1 mile.

An excellent chain for accurate measurements is Grumman's patent "suspended chain," which is made of very light steel wire, is fitted with spring-balance, thermometer and spirit-level attachments, and is held above the surface when in use, the ends of the chain being marked upon the ground by the points of plummets let fall from the end notches.

Instead of a chain, which is liable to error because of the bars and rings becoming worn by frequent contacts, a steel ribbon or tape is often used.

69. Besides the chain or tape, the surveyor needs ten (or better, eleven) marking pins (Fig. 26), made of iron or steel wire, about an eighth of an inch in thickness and a foot long, sharpened at one end and bent into a ring at the other, for marking chain lengths on the ground; a plumbob (Fig. 27) and line for referring, when necessary, points in the chain held horizontally to the inclined surface of the ground; and a set of flag-poles, or ranging rods, for marking stations and ranging out lines. The marking pins should be strung upon an iron ring with a spring-catch, and this ring should be attached to a strap to be passed over the right shoulder suspending the pins at the left side; or, better, the pins may be carried in a leather quiver strapped to the waist.

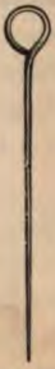


FIG. 26.

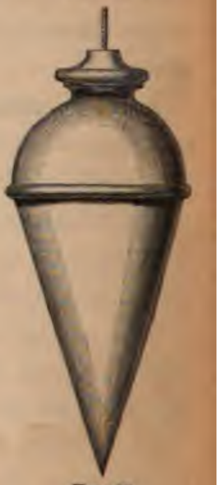


FIG. 27.

The pins should be *tagged* with white cloth to enable the surveyor to find them again readily, when they have been left to mark a point.

70. To Measure a Horizontal Line.—The point where the measurement is to begin is located by a staff temporarily placed for the purpose, or by some one of the many permanent marks by which the angular points in a boundary are fixed.

The other extremity of the line must be provided with a staff or flag which can be easily seen.

Two chainmen are required, a fore-chainman, or leader, and a hind-chainman, or follower. The more careful and expert of the two should be the follower.

The leader, with the marking-pins and one handle of the chain in his right hand, starts off on the line, drawing out the chain to its full length. Both chainmen now examine it to see that there are no inaccuracies in it, either from bent links or kinks in the rings joining the links. Having adjusted the chain for use, the leader resumes his place, to be directed by the follower, who stands behind the staff at the beginning, and sights to the staff at the end of the line, so that the measurement shall be made exactly along the established line.

To facilitate this (on level ground) and to insure the correct alignment of the pin, at its proper distance, the chain and one pin should be held firmly in the right hand, as represented in Figure 28. While the pin is being aligned, it should be held by the leader as far from the body as possible, so that the view of the flag be left unobstructed. To accomplish this, and at the same time draw the chain to the proper degree of tension, the right arm should be braced against the inside of the right knee.

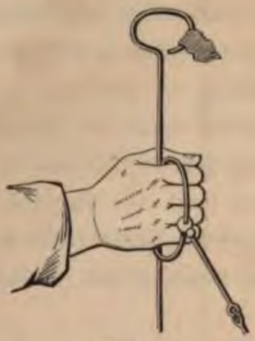
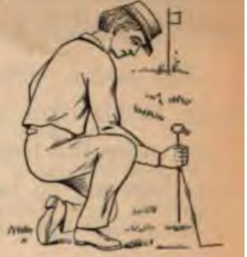


FIG. 28.

The follower directs, by the simple orders "right" or "left," according as the pin, held as described, is to be carried to the right or left to bring it into line with the flag. When the pin is truly in line, the chain at the same time being drawn straight and taut, the order "down" is given, when the leader bringing his left hand to bear on the top of the pin, forces it *vertically* into the ground, and resumes his course to the length of another chain.



"DOWN."

FIG. 29.

If, for any reason, the pin can not be driven into the ground, the end of the chain length should be marked by driving the pin *obliquely*, always at right angles to the chain; if this cannot be done, a cross should be scratched on the ground at the exact point, and the pin laid down with its point at the mark.

After one or two chains have been measured, on any line, the leader can, by glancing back to the station just left, place the pin nearly in the right position; the exact aligning should be left, however, to the follower.

When the distance to be measured is more than ten chains, the pins, when exhausted, should be returned to the leader, the distance noted in a field-book provided for the purpose, and the chaining recommenced at the place of the tenth pin. If but *ten* pins are used, the follower has then but the hole made by the tenth pin to measure from. For this reason, ***eleven*** pins are often used, the eleventh being of different material from the others for distinction, and is used by the follower to measure from when the ten pins are returned to the leader.

71. All distances should be measured horizontally. Hence, when the ground slopes, one end of the chain must be elevated. Each chainman should be provided with a small plumb-line, so that the elevated end of the chain may be held directly over the proper point.

When the raised end of the chain is only two, or even three feet above the ground, it will suffice, in many cases, to use a marking-pin, held lightly by the point, between the thumb and finger, instead of a plumb-line. When the chaining is on a steep inclination, other precautions should be observed.

Suppose the chaining to be *up hill.* The leader ***draws the chain out to its full length,*** as in any other case, and then returns to within such a distance of the follower, that when the chain is drawn out to that length horizontally, it shall not be too high to be held conveniently.

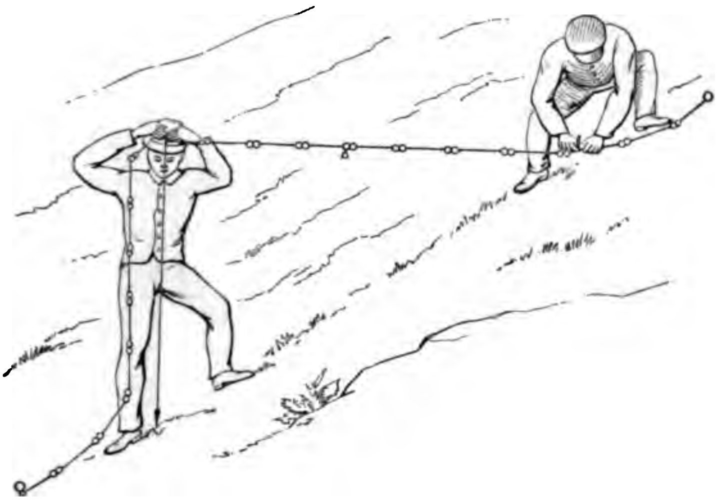


FIG. 30.

The follower holds his end of the chain carefully over the point or station, by means of the plumb-line, while he directs the leader in the usual manner.

The point fixed in this manner, by the leader, must not be marked by a marking-pin, but by a small peg or nail. At the order, "Down," the leader does not go forward immediately, but waits until the follower comes up and takes the chain by the precise point held, the moment before, to the ground.

This point is now held above the peg by the the follower, who uses the plumb, as before, and aligns the leader, who has taken hold of the chain a few links farther on, and is holding it to the ground. These short distances are not recorded. The end of a full chain is marked by a marking-pin.

In chaining *down-hill*, the method is essentially the same. The leader uses the plumb, and determines by it where the peg is to be placed.

At the end of a course, the part of a chain is measured by drawing the chain *only to the flag*, where it is held by the leader, until the follower comes forward to the last pin, and counts the links.

In measuring up the hill from *A* to *C*, or down the hill from *C* to *A*, the horizontal distances *a b*, *c d*, and *f C*, are measured and their sum is the *horizontal* distance between *A* and *C*.

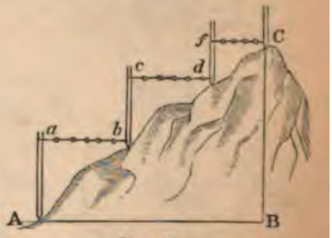


FIG. 31.

Chaining *down* hill gives more accurate results than chaining up; for in chaining down, the follower holds the chain firmly upon the ground and no ordinary pull by the leader moves it. It is impossible to hold a chain perfectly steady *over* a point, by means of a long plumb-line, while the leader is pulling out.

72. When the ends of a line can not be seen, each from the other, intermediate points between the two must be established. When a hill intervenes, such points may be established thus: let the surveyor and an assistant, each with a ranging-rod, place themselves as nearly in the line as possible, and in such position that each can see the other and the flag beyond him. The surveyor looking to the flag at the end of the line, directs the assistant into line with it; the assistant then looks to the flag at the beginning of the line and directs the surveyor into line with it; the surveyor from his new position redirects the assistant into line with the end flag-staff; the assistant then realigns the surveyor with the flag-staff at the beginning of the line; the operation is repeated till both stand in the desired line, when their positions are marked with the ranging-rods.

73. When a valley is to be chained across, intermediate points in the lower portions of it may be fixed, if necessary, by the surveyor holding a plumb-line so as to cover the flag-staffs at both ends of the line and directing an assistant to fix, between the two, ranging-rods which shall also be covered by the plumb-line.

74. When a wood intervenes between the two ends of a line, a *trial line* may be run out by ranging-rods placed at convenient distances in line with each other and with the staff at the beginning of the line, and as nearly as possible in the required line. Then draw on the ground a perpendicular (by a method to be shown presently) from the staff at the end of the required line to the trial line just run out, and measure the length of this perpendicular. The ranging-rods may then, by the property of similar triangles, be put in their true position in line. Thus,

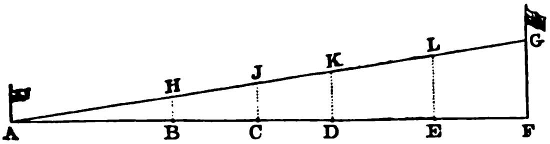


FIG. 32.

AG is to be measured; the *trial line AF* is run out and the ranging-rods *B, C,* &c., fixed at known distances apart and as nearly in the line as possible; the perpendicular *GF* is measured; then from the similar triangles, *AFG* and *ABH,*

$$AF : AB :: FG : BH.$$

The distance *BH* thus becomes known, and the ranging-rod at *B* is moved, on a perpendicular to *AF,* the required distance to its true position at *H.* The other ranging-rods are in like manner put in their true positions at I, K, &c., and the true line is marked out.

75. To trace on the ground the direction of a straight line, that shall be perpendicular, at a given point, to a given straight line.

FIRST METHOD.

Any three lines having the ratio 3, 4, and 5, form a right-angled triangle.

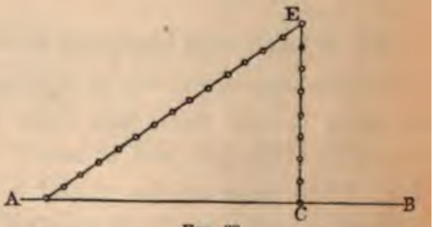


FIG. 33.

Let AB (Fig. 33) be the given line and C the point at which the perpendicular is to be drawn. Divide the number of links in the chain by 8, neglecting the remainder; if we are using the 100-link chain the quotient would be 12 links. From the point C measure a distance towards A equal to four times this quotient (48 links); place one end of the chain at C, and the end of the 96th link $[(5+3)\times 12 = 96]$ at A; then taking the end of the 36th link (3×12) pull out the chain so that the two portions EA and EC are taut, and E will be a point on the perpendicular required.

This method supposes the chain to be *correctly divided* into links.

SECOND METHOD.

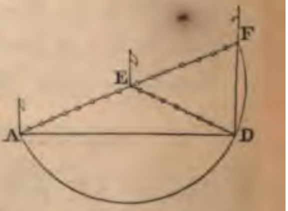


FIG. 34.

Let AD be the given right line, and D the point at which the perpendicular is to be drawn. Take the longest available distance on the tape or chain (the whole of it if possible), and place one extremity at D, and fasten the other at some point, as E, between the two lines which are to form the right angle. Place a staff at *E*. Then, having stationed a person at *D*, remove that extremity of the chain and carry it round until it ranges on the line *DA*, at *A*. Place a staff at *A*: then remove the end of the chain at *A*, and carry it round until it falls on the line *AE*, prolonged, at *F*. Then place a staff at *F*; *ADF* will be a right angle, being an angle in a semicircle.

This method is independent of any errors of graduation of the chain; it also gives the largest possible construction in the field, a matter of importance as insuring the most correct results.

76. There is a simple instrument for laying off right angles on the ground called the *Surveyor's Cross*. This instrument consists of two bars, *AB* and *CD*, Fig. 35, permanently fixed at right angles to each other, and firmly attached at *E*, to a pointed staff, which serves as a support. Four sights are screwed firmly to the bars, by means of the screws *a*, *b*, *c*, and *d*.

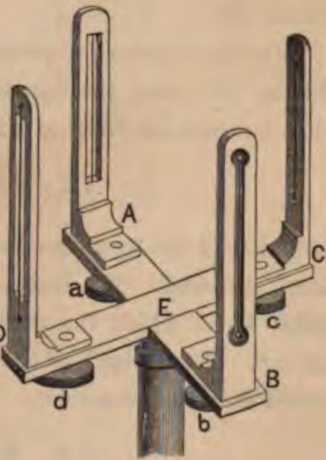


FIG. 35.

As the only use of this instrument is to lay off right angles, it is of the first importance that the lines of sight be truly at right angles. To ascertain if they are so, let the bar *AB* be turned until its sights mark some distinct object; then look through the other sights, and place a staff on the line which they indicate; let the cross be then turned until th hts of the bar *AB* come to this last line; if the oth directed to the first object, the lines of sight are exactly at right angles.

The sights being at right angles, if one of them be turned in the direction of a given line, the other will mark the direction of a line perpendicular to it, at the point where the instrument is placed.

77. From a given point without a straight line, to let fall a perpendicular on the line.—Let C be the given point, and AB the given line (Fig. 36).

From C, measure a line, as CA, to any point of the line AB. From A, measure on AB any distance as AF, and at F erect FE perpendicular to AB.

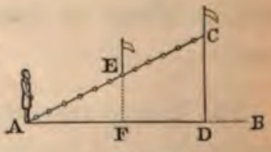


Fig. 36.

Having stationed a person at A, measure along the perpendicular FE until the forward staff is aligned on the line AC: then measure the distance AE. From similar triangles,

$$AE : AF :: AC : AD;$$

in which all the terms are known except AD, which may, therefore, be found. The distance AD being laid off from A, the point D, at which the perpendicular CD meets AB, becomes known. If the length of the perpendicular is desired, it may be found from the proportion,

$$AE : EF :: AC : CD,$$

in which all the terms are known except CD.

It is always best to make AF nearly equal to AD when practicable; for then AE will be nearly equal to AC, and the *multiplication* of errors will be avoided; in the expression $AD = \frac{AC}{AE} \times AF$, $\frac{AC}{AE}$ will be but little greater than 1.

78. To trace on the ground a straight line that shall pass through a given point and be parallel to a given straight line.

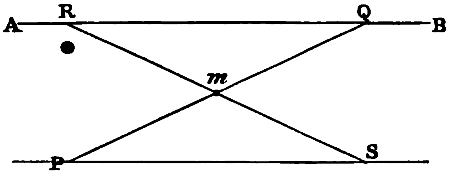


FIG. 37.

Let AB be the given line and P the given point. From P measure any oblique line to AB, as PQ, and mark its middle point, which call m in the figure. From any point of AB, as R, run a line through m, and prolong it till $mS = Rm$; then PS will be the parallel required.

79. To determine the horizontal distance from a given point to an inaccessible object.

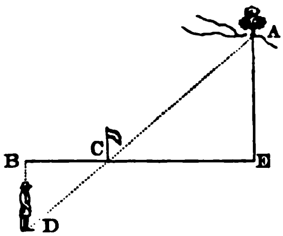


FIG 38.

Let A be an inaccessible object, and E the point from which the distance is to be measured.

FIRST METHOD.—At the point E, lay off EB perpendicular to the line EA, and measure along it any convenient distance, as EB.

At B lay off the right angle EBD, and measure any distance in the direction BD. Let a person at D align a staff on DA, while a second person at B aligns it on BE: the staff will thus be fixed at C. Then measure the distance BC.

The two triangles BCD and CAE being similar, we have,

$$BC : BD :: CE : EA,$$

in which all the terms are known, except the fourth, which is, therefore, found.

If BC can be made equal to CE, then the measured distance BD is the distance required. The triangle BDC should be as nearly equal to *ACE* as practicable, and the angle *BCD* should not exceed 45°.

SECOND METHOD.—Let *B* be the given point, and *A* the inaccessible object; it is required to find *BA*.

Measure any horizontal base-line, as *BC*. Then, having placed staves at *B* and *C*, measure any convenient distances *BD* and *CE*, such that the points *D*, *B*, and *A*, shall be in the same right line, as also, the points *E*, *C*, and *A*; then measure the diagonal lines *DC* and *EB*.

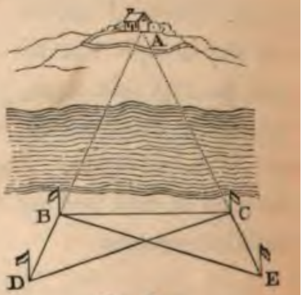


FIG. 39.

Now, in the triangle *BEC*, the three sides are known, therefore, the angle *ECB* can be found. In the triangle *CDB*, the three sides are also known, therefore, the angle *CBD* can be determined. These angles being respectively subtracted from 180°, the two angles *ACB* and *ABC* become known; and hence, in the triangle *ABC*, we have two angles and the included side, to find the side *BA*.

The lines *BD* and *CE* should each equal *BC*, if possible, to facilitate computation, and the angle at *A* should not be less than 40°.

THIRD METHOD.—Let *AC* be the distance required. Lay off the right angle *CAB*, and measure *AB*, any convenient distance. At *B* lay off the right angle *CBD*, and fix the point *D*, carefully, in line with *AC*. Measure *AD*. Then,

$$AD : AB :: AB : AC, \therefore AC = \frac{\overline{AB}^2}{AD}$$

(Legendre, Bk. IV, Prop. 23).

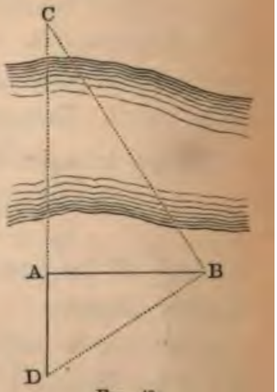


FIG. 40.

NOTE.—When such problems occur

in practice, the distance AC is usually a portion of a longer line, so that the line CAD is well marked by stakes or pins, before AB is measured.

80. To prolong a line beyond an obstacle.—If the obstacle can be seen over, the surveyor should send an assistant, with a flag-pole or ranging-rod, to the further side of it, to a point approximately in line. At this point the assistant should hold the rod vertical and exposed to the surveyor, at one end of the line, who directs him to "right" or "left" till the ranging-rod covers or coincides with the flag-pole at the further end of the line, when it is inserted in the ground and marks a point in the desired line. Other points may be determined in like manner. This is called "ranging," or "ranging out" the line.

When the obstacle cannot be seen over, the continuation may be effected as follows:

FIRST METHOD.—Let OA be the line to be prolonged. Lay off $OAB = 120°$, or $CAB = 60°$. Measure AB, of such length as to permit BC to be measured without meeting the obstruction. Make $ABC = 60°$, and measure BC, equal to AB. If A be not in sight from C, make the angle BCP equal to 120°, and resume the survey of the line. AC is equal to AB or BC.

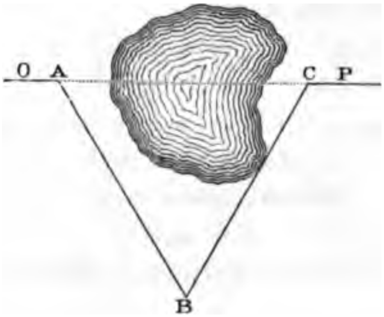


FIG. 41.

NOTE.—This method may be employed in the absence of any angular instruments, by constructing an equilateral triangle with the chain. Measure half a chain from A towards C; then fasten the ends of the chain at A and the point so determined, and pull out the middle, thus forming an equilateral triangle. If there is not room to measure towards C, measure back towards O, and construct the angle on the side of AO away from B. The errors are cumulative in this method, but it is rapid, and will do for work not requiring great accuracy.

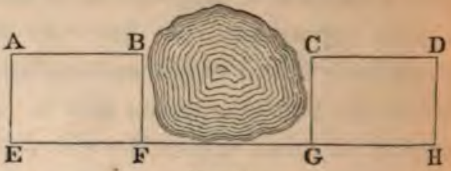


FIG. 42.

SECOND METHOD. Take two points, A and B, at convenient distance apart, one or two chains, and draw two offsets, AE and BF, at right angles to the direction of the line and of sufficient length to clear the obstacle; draw EF through the extremities of the rectangular offsets and prolong it beyond the obstacle; this last line will be parallel to the original line of direction; at G and H draw the lines at right angles to EH, and make them equal in length to AE and BF; draw CD, it will be the prolongation required. FG is equal in length to BC, provided the perpendiculars BF and GC are accurately laid out. This is a good method to use in passing trees or small obstacles, provided the distance between perpendiculars AE and BF, also CG and DH, is one chain or more. The perpendiculars are often laid off by *guess*, which method will give a very fair prolongation, but the distance BC thus obtained will not be accurate.

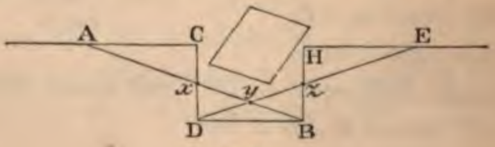


FIG. 43.

THIRD METHOD.—From any point A, measure AB; through its middle point x, run CD, making $Dx = Cx$; then DB will be parallel to AC. From D run a line, DE, through any point of the line AB, as y, making yE of such length that,

$$By : Dy :: Ay : Ey.$$

Then through z, the middle point of DE, run BH, making $zH = Bz$. HE will be the prolongation of AC.

To find CH we have,

$$By : BD :: Ay : AE,$$

from which AE is known;

$$AE - (AC + HE) = CH.$$

81. To find the altitude of an object, when the distance to the vertical line passing through the top of it is known.—Let CD be the altitude required, and AC the known distance.

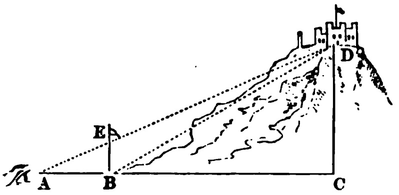


FIG. 44.

From A, measure on the line AC, any convenient distance AB, and place a staff vertically at B. Then placing the eye at A, sight to the object D, and let the point, at which the line AD cuts the staff BE, be marked. Measure the distance BE on the staff; then,

$$AB : BE :: AC : CD,$$

whence CD becomes known.

If the line AC cannot be measured, on account of intervening objects, it may be determined by calculation, as in the preceding article, and then, having found the horizontal distance, the vertical line is readily determined, as before.

82. Standard.—As the chain varies in length from changes of temperature and from use, it should be daily compared with a standard kept for the purpose. A convenient standard for such comparison may be made by driving into a level and even piece of ground two stakes, sawed off even with the surface of the ground, distant from each other one chain, or 66 feet, accurately measured, with nails driven into the heads of the stakes to mark the exact length of the standard. Marks made upon the coping of a wall, or a curb-stone, will answer the same purpose.

If it is found that any line has been measured with either too long or too short a chain, the true distance may be found by the proportion;

The length of the standard
: the length of the incorrect chain used
:: the measured distance
: the true distance.

For areas the proportion would be;

The square of the length of the standard
: the square of the length of the chain used
:: the area found
: the true area.

◆

SECTION II.

AREA OR CONTENTS OF GROUND.

83. The surface of ground being, in general, broken and uneven, it is impossible, without great trouble and expense, to ascertain its exact area or contents. To avoid this inconvenience, it has been agreed to refer every surface to a horizontal plane; that is, to regard all its bounding lines as horizontal, and its area as measured by that portion of the horizontal plane which the boundary lines enclose.

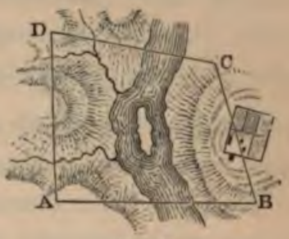


FIG. 45.

For example, if *ABCD* were a piece of ground, having an uneven surface, the whole would be referred to a horizontal plane, and that part of the plane which is included between the bounding horizontal lines *AB*, *BC*, *CD*, *DA*, be taken for the measure of the area.

In estimating land in this manner, the sum of the areas of all the parts, into which a tract may be divided, is equal to the area, estimating it as an entire piece; but this would not be the case if the areas of the parts had reference to the *actual surface*, and the area of the whole were calculated from its bounding lines.

84. The unit of measure of any quantity is a quantity of the same kind, regarded as a standard. For lines, the unit is a right line of a known length, as 1 foot, 1 link, 1 chain, or any other fixed distance. In measuring land, the length of Gunter's chain is generally taken as the unit of linear measure.

85. The unit of measure for surfaces is a square described on the unit of linear measure.

When, therefore, the linear measures are feet, yards, rods, or chains, the superficial measures, are square feet, square yards, square rods, or square chains; and the numerical expression for the area, is the number of times which the unit of superficial measure is contained in the land measured.

An Acre, which is the common unit of measure for land, is a surface equal in extent to 10 square chains; that is, equal to a rectangle of which one side is ten chains and the other side one chain.

A Rood, is one quarter of an acre.

Since the chain is four rods in length, 1 square chain contains 16 square rods; and therefore, an acre, which is 10 square chains, contains 160 square rods, and a rood contains 40 square rods. A *square* rod is called a *perch.*

86. Land is generally computed in acres, roods, and perches, which are respectively designated by the letters *A. R. P.*

When the linear dimensions of a survey are chains or links, the area will be expressed in square chains or square links, and it is necessary to form a rule for reducing such area to acres, roods, and perches. The reduction may be made by the following

TABLE.

Miles.	Acres.	Roods.	Sq. Chains.	Perches.	Sq. Links.
1	640	2560	6400.0	102,400	64,000,000
	1	4	10.0	160	100,000
		1	2.5	40	25,000
			1.0	16	10,000
				1	625

1 square mile = 6400 square chains = 640 acres.

When the linear dimensions are links, the area will be expressed in square links, and may be reduced to acres by dividing by 100,000, the number of square links in an acre; that is, by pointing off *five* decimal places from the right hand.

If the decimal part be then multiplied by 4, and five places of decimals pointed off, in the product, from the right hand, the figures to the left will express the roods.

If the decimal part of this result be now multiplied by 40, and five places for decimals pointed off, as before, the figures to the left will express the perches.

If one of the dimensions be in links, and the other in chains, the chains may be reduced to links by annexing two ciphers; or, the multiplication may be made without annexing the ciphers, and the product reduced to acres and decimals of an acre, by pointing off three decimal places from the right hand.

When both the dimensions are in chains, the product is reduced to acres by dividing by 10, or pointing off one decimal place.

From which it is evident that,

1st. *If links be multiplied by links, the product is reduced to acres by pointing off five decimal places from the right hand.*

2d. *If chains be multiplied by links, the product is reduced to acres by pointing off three decimal places from the right hand.*

3d. *If chains be multiplied by chains, the product is reduced to acres by pointing off one decimal place from the right hand.*

87. Since there are 16.5 feet in a rod, a square rod is equal to

$$16.5 \times 16.5 = 272.25 \text{ square feet.}$$

If the last number be multiplied by 160, there will result

$$272.25 \times 160 = 43560 = \text{the square feet in an acre.}$$

Since there are 9 square feet in a square yard, the last number divided by 9, will give

$$4840 = \text{the number of square yards in an acre.}$$

88. To find the area of a piece of ground in the form of a square, rectangle, or parallelogram.

RULE.—*Multiply the base by the altitude, and the product will express the area* (Geom., Bk. IV., Prop. IV.).

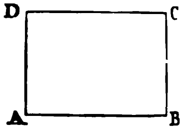


Fig. 46.

Example.—To find the area of the rectangular field $ABCD$.

Measure the two sides AB, BC; suppose that $AB = 14$ chains 27 links, and $BC = 9$ chains 75 links. Then,

$$\begin{array}{rrl} AB = & 1427 & \text{links,} \\ BC = & \underline{975} & \text{links,} \\ AB \times BC = & 1391325 & \text{square links,} \\ = & 13.91325 & \text{acres.} \\ & \underline{4} & \\ & 3.65300 & \text{roods,} \\ & \underline{40} & \\ & \underline{26.12000} & \text{perches.} \end{array}$$

Ans. 13 *A.* 3 *R.* 26 *P.*

89. To find the contents of a piece of land in the form of a triangle.

FIRST METHOD.

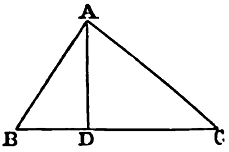


Fig. 47.

Rule.—*Measure either side of the triangle as BC, and from the opposite angle A, let fall a perpendicular AD, and measure this perpendicular; then, multiply the base and perpendicular together, and divide the product by 2; the result will express the area of the triangle* (Geom., Bk. IV., Prop. VI.).

EXAMPLES.

1. What are the contents of a triangle whose base is 25 ch. 1 l., and perpendicular 18 ch. 14 l.? *Ans.* 22 *A.* 2 *R.* 29 *P.*

2. What are the contents of a triangle whose base is 15.48 chains, and altitude 9.67 chains? *Ans.* 7 *A.* 1 *R.* 38 *P.*

SECOND METHOD.

RULE.—*Measure the three sides of the triangle. Then, add them together and take half their sum. From this half sum subtract each side separately. Then, multiply the half sum and the three remainders together, and extract the square root of the product; the result will be the area* (Geom. Mens., Art. **97**).

Or, after having obtained the three remainders, add together the logarithm of the half sum and the logarithms of the respective remainders, and divide their sum by 2; the quotient will be the logarithm of the area.

EXAMPLES.

1. Find the area of a triangular piece of ground whose sides are 20, 30, and 40 chains.

BY FIRST RULE.

$$\begin{array}{rlrlrlrl}
 & 20 & & 45 & & 45 & & 45 \\
 & 30 & & -\underline{20} & & -\underline{30} & & -\underline{40} \\
 & \underline{40} & & \underline{25}\ \text{1st rem.} & & \underline{15}\ \text{2d rem.} & & \underline{5}\ \text{3d rem.} \\
2) & \underline{90} & & & & & & \\
 & 45 = \text{half sum.} & & & & & &
\end{array}$$

Then, $45 \times 25 \times 15 \times 5 = 84375;$

and $\sqrt{84375} = 290.4737 =$ the area.

Ans. 29 *A.* 0 *R.* 8 *P.*

2. What is the area of a triangle whose sides are 2569, 4900, and 5085 links?

BY SECOND RULE.

2569	6252	6252	6252
4900	−2569	−4900	−5035
5035	3683 1st rem.	1352 2d rem.	1217 3d rem.
2) 12504			
6252 = half sum.			

Then,		
	log 6252	3.796019
	log 3683	3.566202
	log 1352	3.130977
	log 1217	3.085291
		2) 13.578489
Area in square links, 6155225 . . .		6.789244

Ans. 61 *A.* 2 *R.* 8 *P.*

90. To find the area of a piece of land in the form of a trapezoid.

RULE.—*Measure the two parallel sides, and also the perpendicular distance between them. Add the two parallel sides together, and take half the sum; then multiply the half sum by the perpendicular, and the product will be the area* (Geom., Bk. IV., Prop. VII.).

EXAMPLES.

1. What is the area of a trapezoid, of which the parallel sides are 30 and 49 chains, and the perpendicular distance between them 16 ch. 60 l., or 16.60 chains?

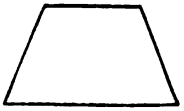


FIG. 48.

$30+49=79$; dividing by 2, gives . . .	39.5
Multiply by	16.60
Area in square chains	655.700

Ans. 65 *A.* 2 *R.* 11 *P.*

2. Required the contents, when the parallel sides are 20 and 32 ch., and the perpendicular distance between them 26 ch.

Ans. 67 *A.* 2 *R.* 16 *P.*

91. To find the area of a piece of land in the form of a quadrilateral.

RULE.—*Measure the four sides of the quadrilateral, and also one of the diagonals; the quadrilateral will thus be divided into two triangles, in both of which all the sides will be known. Then, find the areas of the triangles separately, and their sum will be the area of the quadrilateral.*

EXAMPLE.—Suppose that the sides and diagonal AC, of the quadrilateral $ABCD$ have been found,

$AB = 40.05$ ch., $CD = 29.87$ ch.,
$BC = 26.27$ ch., $AD = 37.07$ ch.,
and $AC = 55$ ch.;

required the area of the quadrilateral.

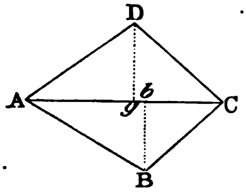


FIG. 40.

Ans. 101 *A.* 1 *R.* 15 *P.*

NOTE.—Instead of measuring the four sides of the quadrilateral, the perpendiculars Bb, Dg, may be let fall on the diagonal AC. The area of the triangle may then be determined by measuring these perpendiculars and the diagonal AC. The perpendiculars are $Dg = 18.95$ ch., and $Bb = 17.92$ ch.

92. To find the contents of a field having any number of sides.

RULE.—*Measure the sides of the field and also the diagonals; the three sides of each of the triangles into which the field will be thus divided will then be known, and the areas of the triangles may then be calculated by the preceding rules.* Or, *measure the diagonals, and from the angular points of the field draw perpendiculars to the diagonals and measure their lengths; the base and perpendicular of each of the triangles will then be known.*

EXAMPLE.—Let it be required to determine the contents of the field $ABCDE$, having five sides.

Suppose that the diagonals and perpendiculars have been found,

$AC = 36.21$ ch., $EC = 39.11$ ch.,
$Bb = 4.08$ ch., $Dd = 7.26$ ch.,
$Aa = 4.19$ ch.;

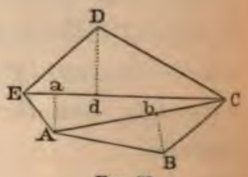


FIG. 50.

required the area of the field.

Area of triangle $ABC = 73.8684$ square chains,
Area of “ $CDE = 141.9693$ “ “
Area of “ $ACE = \underline{81.7399}$ “ “
Area of “ $ABCDE = \underline{297.5776}$ “ “

Ans. 29 *A.* 3 *R.* 1 *P.*

93. To determine the area, when the diagonals and perpendiculars cannot be measured; as in the case of swamp or submerged meadow.

RULE.—*Measure the bounding lines of the area, and then determine the diagonals by outside tie-lines.*

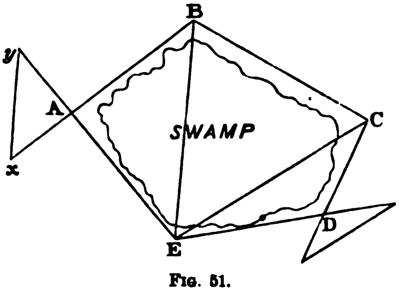


FIG. 51.

Thus, let *ABCDE* represent the polygon including the area, and suppose its sides to be measured. Prolong *BA* to *x*, making *Ax* any exact part of *AB*—say one third—and also prolong *EA* to *y*, *Ay* being one third of *AE*; then, because of similar triangles, the measured length of *xy* will be one third of *BE*. In like manner *CE* may be determined. Having the perimeter and the diagonals proceed as in Art. **92**.

94. To find the contents when the boundary is an irregular line.

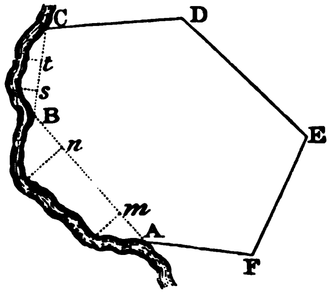


FIG. 52.

It frequently happens that a plot to be surveyed is bounded partly by an irregular line. In such a case, one or more straight lines are surveyed, and offsets measured from these lines, as often as may be required to afford data for the computation of the area and a true delineation of the boundary. In the case represented in the figure, the stream from *A* to *C* is the boundary. The station *B* is selected for convenience, as it is evident, if the line were run direct from *A* to *C*, the labor of taking the offsets would be much greater.

It will be observed that the offsets are so measured as to indicate the abrupt bends in the boundary; and furthermore, so that the areas thus cut off may be considered as being bounded by straight lines, without sensible error.

When the boundary is a crooked stream that is easily crossed, it is often convenient to survey a line across the bend, as in the figure, and locate by offsets upon both sides of the line. In any case, the small areas to be computed are only trapezoids and triangles.

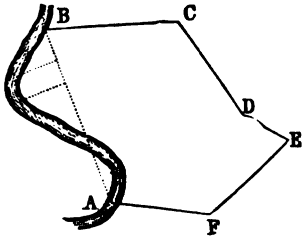


FIG. 53.

95. To find the area of a piece of ground in the form of a circle.

RULE.—*Measure the radius AC; then multiply the square of the radius by 3.1416* (Mens., Art. **105**).

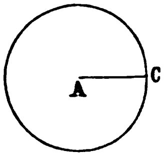


FIG. 54.

To find the area of a circular piece of land, of which the diameter is 25 ch. *Ans.* 49 *A.* 0 *R.* 14 *P.*

96. To find the contents of a piece of ground in the form of an ellipse.

RULE.—*Measure the semi-axes AE, CE. Then multiply them together, and their product by 3.1416.*

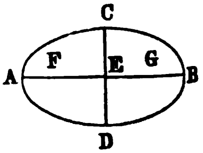


FIG. 55.

To find the area of an elliptical piece of ground, of which the transverse axis is 16.08 ch., and the conjugate axis 9.72 ch.

Ans. 12 *A.* 1 *R.* 4 *P.*

NOTE 1.—The following is the manner of tracing an ellipse on the ground, when the two axes are known.

From *C*, one of the extremities of the conjugate axis as a centre, and *AE*, half the transverse axis, as a radius, describe the arc of a circle cutting *AE* in the two points *F* and *G*; these poins are called the *foci* of the ellipse.

Then, take a tape, the length of which is equal to *AB*, and fasten the two ends, one at the focus *F*, the other at the focus *G*. Place a pin against the tape and move it around, keeping the tape tightly stretched: the extremity of the pin will trace the curve of the ellipse.

NOTE 2.—In determining the contents of ground, in the examples which have been given, the linear dimensions have been taken in chains and decimals of a chain.

If the linear dimensions were taken in terms of any other unit, they may be readily reduced to chains. For, a chain is equal to 4 rods, equal to 22 yards, equal to 66 feet. Hence,

1st. *Rods may be reduced to chains and the decimal of a chain, by dividing by 4.*

2d. *Yards may be reduced to chains and the decimal of a chain, by dividing by 22.*

3d. *Feet may be reduced to chains and the decimal of a chain, by dividing by 66.*

NOTE 3.—If it is thought best to calculate the area, without reducing the linear dimensions to chains, the result can be reduced to acres:

1st. *By dividing it by 160, when it is in square rods* (Art. **85**).

2d. *By dividing it by 4840, when it is in square yards* (Art. **87**).

3d. *By dividing it by 43560, when it is in square feet* (Art. **87**.)

BOOK III.

COMPASS SURVEYING.

SECTION I.

DEFINITIONS.

97. **The Axis** of the earth is the immovable diameter about which it revolves; and the *poles* are the points in which the axis meets the surface.

98. Any plane passing through the axis of the earth is called a *meridian plane;* and its intersection with the surface is called a *meridian line,* or simply a *meridian.*

99. All the meridians converge towards the poles, but they vary so little from parallelism, within the narrow limits of surveys made with the compass, that they may, without sensible error, be regarded as parallel straight lines.

100. If a magnetic needle be suspended freely, and allowed to settle to a state of rest, a vertical plane passed through its axis is called the *plane of the magnetic meridian;* and its intersection with the surface of the earth is called the *magnetic meridian,* or sometimes, a North and South line. A line perpendicular to a North and South line, is called an *East* and *West* line.

101. A line traced, or measured on the ground, is called a *Course;* and the angle which this line makes with the magnetic meridian, passing through the point of beginning, is called the *Bearing*.

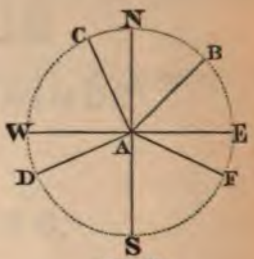


FIG. 56.

Thus, if we start from the point *A*, and measure in the direction *AB*, the line *AB* is the course, and the angle *NAB* is the bearing.

When the course, like *AB*, falls between the north and east points, and makes an angle of 46° with the meridian, the bearing is read, north 46° east, and is written, N. 46° E.

When the course, like *AC*, falls between the north and west points, and makes with the meridian an angle of 30°, the bearing is read, north 30° west, and is written, N. 30° W.

When the course, like *AD*, falls between the south and west points, and makes an angle with the meridian of 70°, the bearing is read, south 70° west, and is written, S. 70° W.

When the course, like *AF*, falls between the south and east points, and makes with the meridian an angle of 70°, the bearing is read, south 70° east, and is written, S. 70° E.

A course which runs due north, or due south, is designated by the letter N, or S; and one which runs due east, or due west, by the letter E, or W.

102. If, after having passed over a course, the bearing is taken to the back station, this bearing is called the *back sight*, or *reverse bearing*.

103. The perpendicular distance between the east and west lines, drawn through the extremities of a course is called the *northing* or *southing*, according as the course is run towards the north or south. This distance is also called the *difference of latitude*, or simply the latitude, because it shows the distance which one end of the course is north or south of the other.

Thus, in running the course from *A* to *B*, *AC* is the difference of latitude, north.

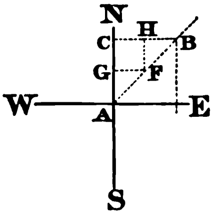


FIG. 57.

104. The perpendicular distance between the meridians passing through the extremities of a course, is called the *departure* of that course, and is east or west, according as the course lies on the east or west side of the meridian passing through the point of beginning.

Thus, in running the course *AB*, *CB* is the departure, east.

105. It is found convenient, in explaining the rules for surveying with the compass, to attribute to the latitudes and departures the algebraic signs, + and —.

We shall, therefore, consider every northing as affected with the sign +, and every southing as affected with the sign —. We shall also consider every easting as affected with the sign +, and every westing as affected with the sign —.

106. The *meridian distance* of a point is its perpendicular distance from any assumed meridian. Thus, if the distance be estimated from the meridian NS, *BC* will be the meridian distance of the point *B*.

107. The meridian distance of a *line*, is the meridian distance of its *middle point*, and is east or west, according as this point lies on the east or west side of the assumed meridian. Thus, *FG* drawn through the middle point of *AB*, is the meridian distance of the line *AB*.

The sign + will always be given to the meridian distance of a point or line, when it lies on the east of the assumed meridian, and the sign —, when it lies on the west.

SECTION II.

SURVEYOR'S COMPASS.

108. The Surveyor's Compass consists of a compass-box, *DCE*; a magnetic needle; a brass plate, *AB*, from twelve to fourteen inches long; two plane sights, *AF* and *BG*; two spirit-levels placed at right angles to each other; a brass head, *K*, to fit the compass to a stand, which is sometimes a tripod and sometimes a single staff, called Jacob-staff, pointed with iron at the lower end so that it may be placed firmly in the ground.

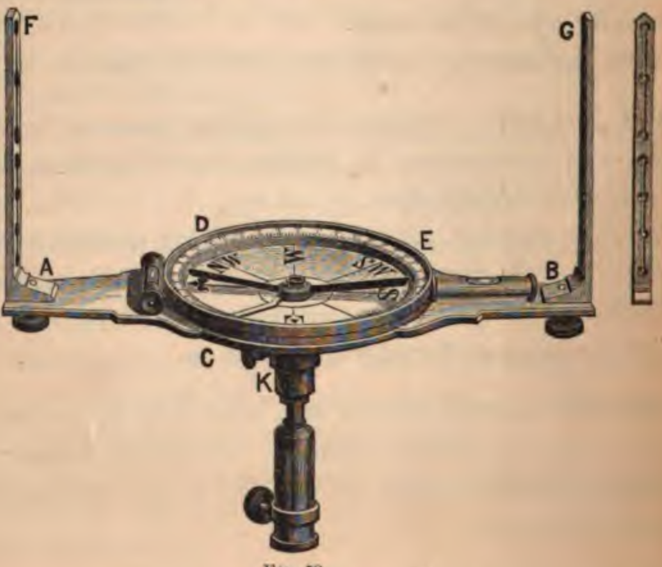


Fig. 58.

109. The compass-box *DCE* is circular, and generally about six inches in diameter. At the centre is a small pin, on which the magnetic needle is poised. This needle, if allowed to turn freely around the point of support, will settle to a state of rest;

the direction which it then indicates, is that of the *magnetic meridian.*

In the interior of the compass-box, there is a graduated circle divided to degrees, and half degrees; the degrees are numbered from the extremities of the diameter NS, both ways to 90°.

The length of the magnetic needle is a little less than the diameter of the graduated circle, so that the needle can move freely around its centre, within the circle, and its positions be noted on the graduated arc.

110. The open sights, AF and BG, are placed at right angles to the plate AB, and fastened to it firmly by screws. The sights have fine slits cut through nearly their whole length, interrupted at intervals by large circular apertures through which the object sighted upon is more readily found, as shown in the figure.

111. The spirit-level is a small glass tube, slightly curved toward the middle, nearly filled with alcohol, leaving a bubble of air in the tube, and closed at both ends. When the level is in a truly horizontal position, the bubble of air rests in the middle of the tube; when the level is not horizontal, the bubble seeks the more elevated end. When the two levels have each the bubble at the middle, each is truly horizontal and their plane is horizontal; therefore, the plane of the graduated circle and the magnetic needle, which is parallel to the plane of the levels, is, also, horizontal.

112. The brass-head, by which the compass is attached to the staff, is furnished with a ball-and-socket joint to give a universal motion for purpose of leveling. Sometimes a tripod is used as a support instead of a staff, in which case a plumb-bob is attached immediately under the centre of the graduated circle for the purpose of *accurately* placing the instrument over any desired point. When a tripod is used, a tripod-head with leveling screws (to be described under the transit), instead of a ball-and-socket joint, is often used for leveling. In the description which follows, a ball-and-socket joint will be assumed.

113. To find the bearing of any course by the compass. Let *PQ* be the course whose bearing is desired. Place the compass exactly over the point *P*, by inserting the staff in the ground at that point, or by the plumb-bob if a tripod is used. It is usual for a surveyor to keep the south end of the compass towards him and to read the bearings from the north end, and this position of the compass will be assumed in description, unless otherwise stated. Turn the sights toward the staff or object at *Q*. Bring the bubbles to the middle of the spirit-levels by the pressure of the hand on different parts of the plate. Look through the small slit in the sight next the person, and turn the compass till the small slit in the sight opposite bisects the object at *Q*, being careful to keep the bubbles at the middle of the levels. Let the needle come to rest and take the reading indicated by the north end of the needle—it will be the angle *NPQ*, the bearing. When the needle is at rest, it lies in the magnetic meridian. The line of sights lies in the direction of the course; when this line lies *east* of the meridian, the bearing is *east*; when it lies *west* of the meridian, the bearing is *west*. When the bearing is *east*, the needle lies to the *west* of the line of sights, and the reverse; hence, to facilitate the reading the E and W letters on the face of the compass are reversed from their natural position.

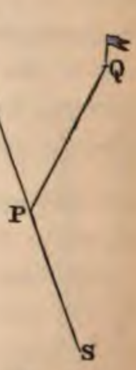


FIG. 59.

In order to prevent a merely *mechanical reading*, the cover of the compass-box should be unscrewed and a circle of paper should be fitted into the bottom of the box so as to conceal the letters; the student will then learn to read from the needle alone, the north end of which bears a distinguishing *mark* or *color*. It is only by such practice that blundering readings can be avoided.

114. To find by the compass the angle subtended at any point by two objects, take the bearing of the course to each object, as explained in the last article. The question then is to find the angle between any two courses, when their bearings are known, which may be done as follows:

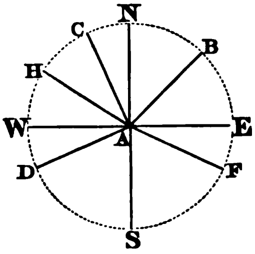


FIG. 60.

Let NS be a meridian passing through *A*.

Let *AB*, *AC*, *AH*, *AD*, and *AF*, be five courses running from *A*. We readily deduce the following

PRINCIPLES.

AC is N 26° W
AH is N 65° W
CAH = 39°

When the meridional letters are alike, and those of departure also alike, *the difference of the bearings is the angle between the courses.*

AB is N 46° E
AC is N 26° W
CAB = 72°

When the meridional letters are alike, and those of departure unlike, *the sum of the bearings is the angle between the courses.*

$$\left.\begin{array}{r} AC \text{ is N } 26^\circ \text{ W} \\ AD \text{ is } \underline{\text{S } 66^\circ \text{ W}} \\ CAD = 180^\circ - 92^\circ = 88^\circ \end{array}\right\}$$

When the meridional letters are unlike, and those of departure alike, *the angle between the courses is equal to 180°, minus the sum of the bearings.*

$$\left.\begin{array}{r} AC \text{ is N } 26^\circ \text{ W} \\ AF \text{ is } \underline{\text{S } 66^\circ \text{ E}} \\ CAF = 180^\circ - 40^\circ = 140^\circ \end{array}\right\}$$

When the meridional letters are unlike, and those of departure also unlike, *the angle between the courses is equal to 180°, minus the difference of the bearings.*

NOTE.—The above principles are deduced, under the supposition that the two courses are both run from the same angular point. Hence, if it be required to apply these rules to two courses run in the ordinary way, as we go around the field, the bearing of one of them must be *reversed* before the calculation for the angle is made.

EXAMPLES.

1. The bearings of two courses, from the same point, are N 37° E, and S 85° W; what is the angle included between them? *Ans.* 132°.

2. The bearings of two adjacent courses, in going round a piece of land, are N 39° W, and S 48° W; what is the angle included between them? *Ans.* 87°.

3. The bearings of two adjacent courses, in going round a piece of land, are S 85° W, and N 69° W; what is the angle included between them? *Ans.* 154°.

4. The bearings of two adjacent courses, in going round a piece of land, are N 55° 30′ E, and S 69° 20′ E; what is the angle included between them? *Ans.* 124° 50′.

SECTION III.

WORK ON THE FIELD.

n a piece of ground is to be surveyed, we begin at ent corner of the field and go entirely around the ring the lengths of the bounding lines with the aking their bearings with the compass. It is not ether the ground be kept on the right hand or on d all the rules deduced for one of the cases, are licable to the other. To preserve uniformity, how- language of the rules, we shall suppose the land to be t on the right hand of the

BCD be a piece of ground rveyed, A the point where is to be begun, and NS a n.

a sheet of paper, *rule a single , ½ inch wide, down the middle eft hand page of the note book, he example.*

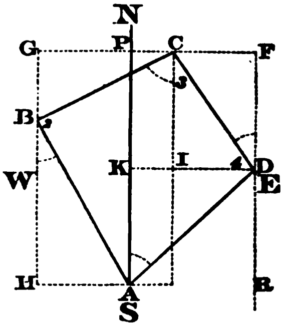


Fig. 61.

A	Δ	(N. 45 E.)
	10.00	
		S. 45½ W.
D	Δ	(N. 35½ W.)
	7.60	
		S. 36 E.
C	Δ	(S. 62 W.)
	9.20	
		N. 62 E.
B	Δ	(S. 31½ E.)
	10.40	
A	Δ	N. 31½ W.

Place the compass at A, and take the bearing to B, which is PAB; suppose this angle has been found to be 31½°. The bearing from A to B is then N. 31½° W. Enter this bearing in the field notes at the right of station A. Then measure the distance from A to B, which we will suppose to be 10 ch. 40 l., and insert that distance in the column, above the station mark.

We next take the bearing from B to C, N. 62° E., and then measure the distance $BC = 9$ ch. 20 l., both of which we insert in the notes as above.

At station C we take the bearing to D, S. 36° E., and then measure the distance $CD = 7$ ch. 60 l., and place them in the notes.

At D we take the bearing to A, S. 45½° W., and measure the distance $DA = 10$ ch. We shall then have made all the measurements on the field which are necessary to determine the contents of the ground.

116. The reverse-bearing or back-sight, from B to A, is the angle ABH; and since the meridians NS and HG are parallel, this angle is equal to the bearing NAB. The reverse-bearing is, therefore, S. 31½° E, *and should be entered in the notes in parenthesis opposite station B, as in the example.*

The reverse-bearing from C, is S. 62° W.; that is, it is the angle $ICB = GBC$. And generally,

A reverse-bearing, or back-sight, should always equal the forward-bearing, and differ from it only in both of the letters by which it is designated.

117. In taking the bearings with the compass, there are two sources of error. 1st. The inaccuracy of the observations; 2d. Local attractions, or the derangement which the needle experiences when brought into the vicinity of iron-ore beds, or any ferruginous substances.

To guard against these sources of error, the reverse-bearing should be taken at every station; if this and the forward-bearing are of the same value, the work is probably right; but if they differ considerably, they should both be taken again.

Electricity is a fruitful cause of annoyance in compass work. In cold, dry weather, any friction upon the glass cover of the needle-box, even that of a cold, dry wind, charges it with electricity and the needle no longer traverses freely. To dissipate the charge touch the plate with a moistened finger, or breathe strongly upon it. If the surveyor uses a pocket lens to read the needle, he must see to it that no iron or steel screws are used in the casing; nickel-plated mountings are not admissible; hard rubber mountings are very troublesome, as they often become highly charged, and will drag the needle through 90°, or even 180°. Brass, or German silver, are the most satisfactory mountings.

118. In passing over the course AB, the northing is found to be HB, and the departure, which is west, is represented by AH. Of the course BC, the northing is expressed by BG, and the departure, which is east, by GC. Of the course CD, the southing is expressed by CI, and the departure, which is east, by CF. Of the course DA, the southing is expressed by KA, and the departure, which is west, by DK. It is seen from the figure, that the sum of the northings is equal to $HB+BG = HG$; and that the sum of the southings is equal to $CI+KA = PA = HG$; hence, *the sum of the northings is equal to the sum of the southings.*

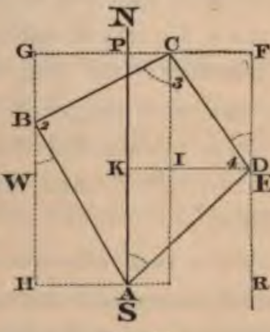


FIG. 62.

If we consider the departures, it is apparent that the sum of the eastings is equal to $GC+CF=GF$; and that the sum of the westings is equal to $AH+DK=GF$; hence, *the sum of the eastings is equal to the sum of the westings.* We therefore see, that when the survey is correct, *the sum of the northings will be equal to the sum of the southings, and the sum of the eastings to the sum of the westings.*

It would, indeed, appear plain, even without a rigorous demonstration, that after having gone entirely round a piece of land, the distance passed over in the direction due north must be equal to that passed over in the direction due south; and that the distance passed over in the direction due east must be equal to that passed over in the direction due west.

119. The boundaries of a field are generally occupied by fences, and frequently also by a border of shrubbery, so that chaining along the true boundary is impossible.

In such cases, it becomes necessary to measure an offset at each end of the course (and at right angles to it), and of sufficient length to clear the obstructions; the measurement is then made between these temporary stations.

It is evident that the bearing and length of *mn*, the offset-course, are the same as those of *MN*.

When such offset-courses are necessary for several successive courses, errors are likely to be committed, unless the surveyor is careful to make new offsets for each course.

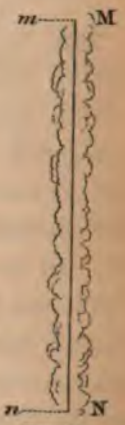


FIG. 63.

To survey boundaries LM, MN, NO, &c., along which the chaining cannot be done, as in Fig. 64, proceed thus:

Set the instrument at some point, *A* for example, far enough from *LM* to clear all obstacles, usually five or six feet; next

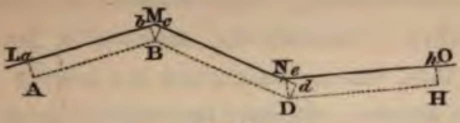


FIG. 64.

lace a pole at B, make $Bb = Aa$ by measurement, laying off the erpendiculars by the eye alone; now sight B and note the reading. Vhile the compass is sighted on B, look across two notches cut in he rim of the compass-box in a line perpendicular to the line of the ights and passing through the needle pivot, and fix a plumb-line pon LM, as at a; if the distance Aa, when re-measured, should iffer much from that used in setting off Bb, the offsets must be orrected; now measure La (a few links only), and, transferring he link held at a to A, continue the measurement along AB to B; having set up the compass at B, sight to A for the back-ight, or reverse-bearing, and at the same time fix a plumb-line t b by "cross-sighting" as before; transfer the link held at B o b, and continue to M, and enter the length of LM, thus btained, in the notes.

Without moving the instrument, measure the perpendicular Bc, set a staff at D and make Dd, the perpendicular to MN pro-onged, equal to Bc; sight to D for the bearing of MN, cross-ight to fix c, and do the same at D to fix d; measure Mc, BD, dN; $Mc + BD - dN = MN$, which enter in the notes. In like manner, $NO = Ne + DH + hO$.

120. It has been customary, since the first settlement of this ountry, to use the compass in all land surveys, so that the escription of lands, in purchase and sale, and by which they re recognized in the courts, involves the length and bearing f each straight line of the boundary. The method, therefore, s, at present, a necessary one.

The errors to which the compass is liable are so numerous nd so variable, even in the same instrument, that a change of practice is very desirable. Many surveyors, to insure a higher degree of accuracy, measure the angles of a field with the transit, and then, having determined the bearing of one side with sufficient accuracy, calculate the others by a method to be shown in a subsequent article.

121. In surveys of large areas, the surveying party should consist of at least four persons—viz., a compass-man, a flag-man, and two chain-men. In smaller areas, the work is generally performed by the surveyor and one assistant; the surveyor serving alternately as compass-man and hind-chainman, and the assistant as flag-man and fore-chainman.

122. In recording the notes of the survey, the advantage of beginning at the bottom of the page is this: that when standing on the line to be surveyed, and looking in the direction we propose to go, the column in the book lies before us just as the line does, and all measurements made to the right or left of the line are recorded at the right or left of the column. In surveys where many auxiliary notes are taken, a diagram is an important aid to a ready interpretation of the other notes.

GENERAL EXAMPLE.

123. To explain the method, in full, of making a compass survey and recording the notes, we will take an example of a farm, in which, in addition to the usual survey of the boundary, such other measurements are made as to enable us to make a correct map of the whole.

Page 87 represents a farm to be surveyed, and page 86, the notes which are made, in the operations on the field.

Beginning with the corner marked *A*, the bearing of the line *AB* is taken. In most cases, offsets from both *A* and *B* we [illegible] taken, in order that the survey may be clear of the [illegible] ch offsets are not recorded; the surveyor must keep in mind that it is the *boundary of the field* that is surveyed, and any device by which this is accomplished is no part of his notes.

The record of the bearing of the first course is entered at the right of the column (page 86), while the letter designating the station, is placed to the left.

The symbol △, which signifies station, is placed in the column, between the letter and the bearing, for each angle of the farm.

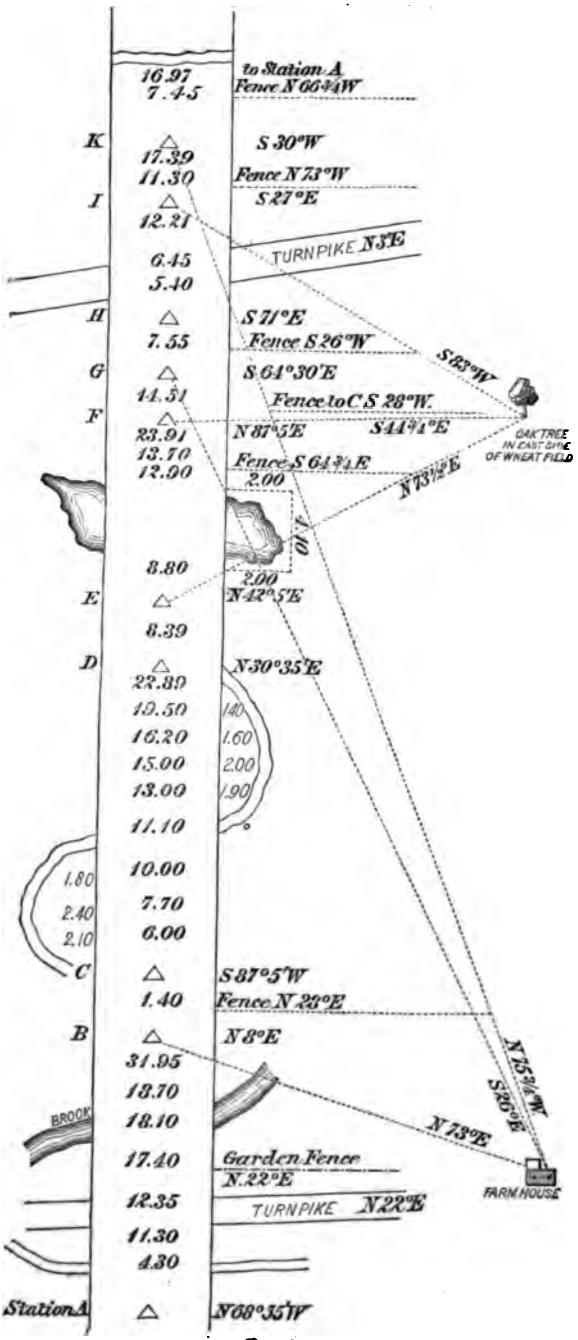
In chaining the first course, the intersection of the line with any objects worthy of notice is recorded. The first record is of the road leading to the quarry. As it is an unimportant road, a single measurement of the distance on the course to its centre is sufficient to locate it. The distance is 4.30 chains.

At 11.30 and 12.35 the sides of the turnpike are intersected. The bearing of the road, at this point, is also carefully taken and recorded.

The intersections of the garden fence and of the brook are also noted (17.40) and (18.10); and these, with the entire length of the course (31.95), close the record of this line.

At *B*, the back-sight upon *A* is first taken, and entered in the notes opposite the *B*-station mark, as directed in Art. **116**. The entry is omitted in the example to avoid *crowding* and confusing the notes. Then the bearing of *BC* is taken. Next the bearing of the northernmost chimney of the farm-house is taken (N. 73° E.). Such bearings serve two purposes. They aid in the location of the objects observed, upon the map, and serve also, in case of errors, to aid in detecting their location.

In general, in surveying large or small areas, some prominent point or points, within the boundary, should be selected, and their bearings, from different angles, carefully noted.



16.97
to Station A
7.45
Fence N 66¾W
K
S 30°W
17.39
11.30
Fence N 73°W
I
S 27°E
12.21
TURNPIKE N3°E
6.45
5.40
H
S 71°E
7.55
Fence S 26°W
S 83°W
G
S 64°30′E
14.51
Fence to C S 28°W.
F
23.91
N 87°5′E
S 44¾°E
OAK TREE IN EAST SIDE OF WHEAT FIELD
13.70
12.90
Fence S 64¾E
2.00
N 73½°E
4.10
8.80
2.00
E
N 42°5′E
8.39
D
N 30°35′E
22.80
19.50
1.40
16.20
1.60
15.00
2.00
13.00
1.90
11.10
10.00
1.80
7.70
2.40
6.00
2.10
C
S 87°5′W
1.40
Fence N 23°E
B
N 8°E
31.95
18.70
BROOK
18.10
N 75¾°W
S 20°E
N 73°E
17.40
Garden Fence N.22°E
FARM HOUSE
12.35
TURNPIKE N22°E
11.30
4.30
Station A
N 68°35′W

FIG. 65.

MAP OF FARM.

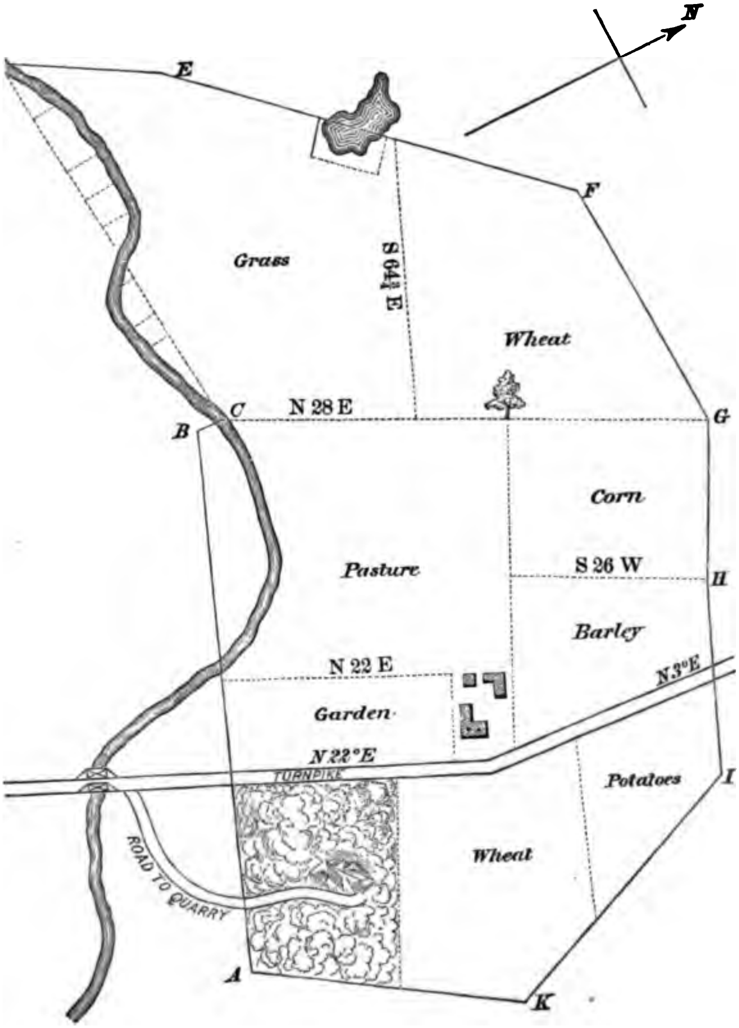


Fig. 66.

The chimney of the farm-house and the oak-tree in the corner of the wheat-field, are thus employed in this survey.

At *C*, the corner of the field, is in the centre of the brook, and from this point to *D*, the brook is the boundary. A straight line is run between the stations, and offsets are measured to each bend of the brook.

It is necessary, in such a case, for the chainmen to exercise unusual care in keeping in the line between the stations, otherwise the lengths of the offsets cannot be correctly measured.

At *E*, the bearing of the oak-tree is taken (N. 73½° E.). On the course between *E* and *F*, a marsh is encountered, which the chainmen pass, by an offset course.

At *F*, another bearing is taken of the oak-tree (S. 44¼° E.).

At *G*, the bearing of the farm-house chimney is noted (S. 26° E.). At *G* and *H* the bearings of the division-fences are taken. On the course from *H* to *I*, the turnpike is again crossed; the intersection of both sides, together with the bearing, are carefully noted.

From *I* to *K*, the intersection and bearing of the fence between the potato and the wheat field, are recorded. The course from *K* to *A* closes the survey.

To locate the buildings about the farm-house, a few measurements would be necessary; but they may begin with the point already located by the bearings taken to the chimney nearest the north end of the house.

The dimensions of the buildings, their distances apart, and the direction of one side of each afford sufficient data for locating them, correctly, upon the map.

NOTE.—The advantage of the compass over other instruments with which angles are measured, lies chiefly in this: that the Bearing of a course may be measured at any point on the line.

When the angle between adjacent sides is taken with the Transit, the work can only be done at the corners of the field; and when, as frequently happens, a hill intervenes between two consecutive stations, it becomes necessary to locate a point on the hill, in the true line, and then return to the corner to measure the angle; whereas, when the compass is employed, the establishment of the intermediate point on the hill affords the means of taking the proper bearing without going to the angle. Furthermore, the bearings may be measured with the compass, by placing it at the alternate stations only.

The disadvantage of these rapid methods is that there is no check upon the needle readings, as there is in back-sighting.

124. To Correct Local Attraction.—Suppose that bearings and reverse-bearings have agreed for several stations, and that then a back-sight differs from the preceding fore-sight; it may be concluded that local attraction affects the needle at the last station only.

Suppose the fore-sight at *P* to have been N. 30 E., and the back-sight at *S* to be S. 28 W.; suppose the fore-sight at *S* to be N. 26 W.; what is the correct fore-sight at *S*? From Fig. **67** we see that the needle at *S*, instead of being parallel to the needle at *P* (as indicated by the dotted needle) as it should be, has been deflected by local attraction (as shown by the full needle), so that its south end is moved 2° to the W., and its north end 2° to the E. of its proper position. Hence the fore-sight at *S*, being taken from the needle in a false position, is 2° too large, and should be only N. 24 W. By similar reasoning, aided by a mental picture of the case, any bearing may be corrected.

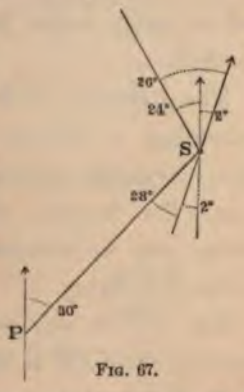


FIG. 67.

If no back-sight and its fore-sight agree, then take the mean of the back-sight and fore-sight which differ least; or seek some ground at a distance, free from local attraction, and then work into the plot to be surveyed, correcting each fore-sight on the way.

SECTION IV.

AREA OR CONTENTS OF GROUND.

Having explained the necessary operations on the field, we shall now proceed to show the manner of computing the contents of ground.

125. The Traverse Table and its Uses.—This table shows the latitude and departure corresponding to bearings that are expressed in degrees and quarters of a degree, from 0 to 90°, and for every course from 1 to 100, computed to two places of decimals.

The following is the method of deducing the formulas for computing a traverse table; by means of these formulas and a table of natural sines, the latitude and departure of a course may be computed to any desirable degree of accuracy.

Let AD be any course, and NAD its bearing; then AE is the *latitude,* and ED the *departure* of the course AD, to the bearing NAD. From Art. **36**, we have (using nat. sines)

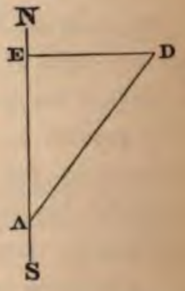


FIG. 68.

$$AD : AE :: 1 : \cos NAD.$$

Whence, lat. = course × cosine of bearing.

And from Art. **32**, we have (since sine $AED = 1$),

$$AD : ED :: 1 : \text{sine } NAD.$$

Whence, dep. = course × sine of bearing.

We have then the following practical rule for computing the latitude and departure of any course.

Look in a table of natural sines for the cosine and sine of the bearing. Multiply each by the length of the course, and the first product will be the latitude, and the second will be the departure of the given course.

EXAMPLES.

1. The bearing is 65° 39′, the course 69.41 chains: what is the latitude, and what the departure?

Natural cosine of 65° 39′	.41231
Length of the course	69.41
Product, which is the Dif. of Lat.	28.6184371
Natural sine of 65° 39′	.91104
Length of the course	69.41
Product, which is the Departure	63.2352864

2. The bearing is 75° 47′, the course 89.75 chains; what is the latitude, and what the departure?

Natural cosine of 75° 47′	.24559
Length of course	89.75
Product, which is the Dif. of Lat.	22.0417025
Natural sine of 75° 47	.96937
Length of course	89.75
Product, which is the Departure	87.0009575

In this manner, the traverse table given at the end of the book, has been computed. When the bearing is given in d and quarters of a degree, and the difference of latitude and departure are required to only two places of decimals, they may be taken directly from the traverse table.

When the bearing is less than 45°, the angle will be found at the top of the page; when greater, at the bottom. When the distance is less than 50, it will be found in the column "distance," on the left-hand page; when greater than 50, in the corresponding column of the right-hand page.

126. The latitudes or departures of courses of different lengths, but which have the same bearing, are proportional to the lengths of the courses. Thus, in the figure, the latitudes *AG*, *AC*, or the departures *GF*, *CB*, are to each other as the courses *AF*, *AB*.

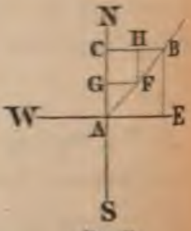


FIG. 69.

Therefore, when the distance is greater than 100, it may be divided by any number which will give an exact quotient less than 100; then the latitude and departure of the quotient being found and multiplied by the divisor, the products will be the latitude and departure of the whole course. It is also plain, that the latitude or departure of two or more courses, having the same bearing, is equal to the sum of the latitudes or departures of the courses taken separately.

It is always better to obtain the lat. and dep. by addition than by multiplication; thus, if we sought the lat. and dep. of a course of 190 ft., bearing 36°, they would be found by multiplication thus,

$$\text{lat. } 19 \times 10 = 15.37 \times 10 = 153.70$$
$$\text{dep. } 19 \times 10 = 11.17 \times 10 = 111.70$$

giving results containing ten times the error of lat. and dep. of 19, as given in the table. By addition we should have

$$\text{lat. } 100 + \text{lat. } 90 = 80.90 + 72.81 = 153.71$$
$$\text{dep. } 100 + \text{dep. } 90 = 58.78 + 52.90 = 111.68$$

which are closer approximations than the former.

Hence, we should always make our multipliers as small as possible.

EXAMPLES.

1. To find the latitude and departure of 614, to bearing 29½°.

Latitude of	100 × 6 =	522.24	Departure of	100 × 6 =	295.44
Latitude of	14 =	12.18	Departure of	14 =	6.89
Latitude of	614	534.42	Departure of	614 =	302.33

2. To find the latitude and departure for the bearing 62½°, and the course 7855 chains.

Latitude for	7800 .	3602.00	Departure for	7800 .	6919.00
Latitude for	55 .	25.40	Departure for	55 .	48.79
Latitude for	7855 .	3627.40	Departure for	7855 .	6967.79

NOTE.—When the distances are expressed in whole numbers and decimals, the manner of finding the latitudes and departures is still the same, except in pointing off the places for decimals; but this is not difficult, when it is remembered that the column of distances in the table may be regarded as decimals, by simply removing the decimal point to the left in the other columns.

3. To find the latitude and departure for the bearing 47¾°, and the course 37.57.

Latitude for	37.00 . .	24.88	Departure for	37.00 .	27.39
Latitude for	.57 . .	.38	Departure for	.57 .	.42
Latitude *for*	*37.57* . .	*25.26*	Departure for	37.57 .	27.81

127. Balancing the Work.—The field-notes having been completed, rule a new table, as below.

Then find, from the traverse table, the latitude and departure of each course, and enter them in the proper columns opposite the station.

Then add the column of northings, and also the column of southings; the two sums should be equal to each other. If they are not, subtract the less from the greater; the remainder is called the *error in latitude.* Find the error in departure in the same way.

This error for latitude or departure must be distributed among the latitudes or departures of all the courses, in proportion to the length of each course, observing to *add* the correction, when applied to the deficient column, and to *subtract* it, when applied to the other.

This may be illustrated by the example of (Art. **115**).

Stations.	Bearings.	Dis.	Dif. Lat.		Dep.		Balance.	
			N. +	S. −	E. +	W. −	Lat.	Dep.
A	N. 31½° W.	10.40	8.87	....	....	5.43	+8.86	−5.44
B	N. 62° E.	9.20	4.32	...	8.13		+4.31	+8.12
C	S. 36° E.	7.60	·	6.15	4.47		−6.15	+4.46
D	S. 45½° W.	10.		7.01		7.13	−7.02	−7.14
Sum of courses,		37.20	13.19	13.16	12.60	12.56		
			13.16		12.56			

Error in latitude . . .03 .04 Error in departure.

The error in latitude, 3 links, is to be distributed among the northings and southings, in proportion to the lengths of the courses; a part to be *added* to the southings, and the remaining part *subtracted* from the northings. The error in departure is similarly distributed among the eastings and westings. For this, two new columns are formed, called, the *balanced* latitudes and departures; and to these columns the latitudes and departures are transferred, after the corrections have been made; the north latitudes being marked +, and the south latitudes —, in order to distinguish them readily, and also, for convenience in the calculations which follow.

The error of .03 in the latitudes is distributed among the latitudes, by subtracting 1 link from each of the northings of courses A and B, and adding 1 link to the southing of course D. This produces a balance.

Of the error of 4 links in the departures, 1 link is added to each of the departures west, and 1 link subtracted from each of the departures east. This produces a balance.

NOTE.—When a knowledge of the conditions under which the survey was made, enables us to determine that errors were more likely to occur at certain points, it is best to apply the corrections to those courses where it seems probable the errors were made.

128. The limit of error to be allowed depends, of course, upon the importance of the survey.

In ordinary farming districts, the error should be as small as 1 link to 5 or 10 chains of perimeter.

The "error of the survey" should be considered as the length of the line necessary to *close the boundary*, and is equal to the square root of the sum of the squares of the errors of latitude and departure. Thus, in the above example, the error of the survey is 5 links. The perimeter being 37.20 chains, the error is about 1 link to 7.45 chains, or $\frac{1}{745}$ of the perimeter.

129. It will be well to bear in mind the fact, that if the error in the perimeter has been made in one course only, and distributed, by the ordinary methods of balancing, among *all* the courses, the error in area will be larger than the error in perimeter.

130. When the error is so large that a re-survey becomes necessary, the *balancing* should be carefully re-examined. In many cases, the location of the error may be determined by inspection of the computation, and a portion of the labor of a re-survey thereby saved.

This refers more particularly to those cases where the error is one of chaining, and is mostly in one course. Errors of this kind occur sometimes with experienced chainmen, who draw the chain properly between the courses, but make occasionally an error in counting the fractional part of a chain at the end of a course. In such cases, the location of the error may be detected by observing, first what columns contain errors, and secondly the ratio of the errors of Latitude and Departure.

When the error in the survey has been a single one, of distance only, then the ratio between the errors of Latitude and Departure must be the same as the ratio between the Latitude and Departure of the course to be corrected. If the errors be in northings and westings, then the courses running either North and West, or South and East, should be examined.

131. The surveyor should take every possible precaution against errors in the bearings. This is accomplished by backsighting, taking bearings of some one object from several stations, and also by taking bearings of stations *across* the field. These precautions will give, in general, sufficient data for the detection of an error in *bearing;* for, by mapping the survey and drawing the lines to indicate the extra bearings, the error is revealed by the failure of the lines to meet at a common point.

132. One source of error, in large surveys with the compass, is frequently overlooked. This is the *diurnal* variation; there is sometimes as much as 15 minutes variation during the daylight hours.

Errors from this source can only be avoided by testing the compass, at intervals of two or three hours, by taking the bearing of the same line.

133. There is one kind of error frequently made in reading the compass when the bearing is nearly east or west. The error arises from reading North for South, or the reverse. If the survey is otherwise correct, the error in latitude is just twice the latitude of the course containing the error.

DOUBLE MERIDIAN DISTANCES

134. After the work has been balanced, the next thing to be done is to calculate the double meridian distance of each course.

For this purpose, any meridian line may be assumed. It is, however, most convenient to assume that meridian which passes through the most easterly or westerly station of the survey; and these two stations are readily determined by inspecting the field-notes.

Having chosen the meridian, let the station through which it passes be called the *principal station*, and the course which begins at this point, *the first course. Care, however, must be taken not to confound this with the course which begins at station 1, and which is the first course that is entered in the field-notes.*

It has already been remarked (Art. **105**), that all departures in the direction east are considered as *plus*, and all departures in the direction west as *minus*.

135. To deduce a rule for finding the double meridian distance of any course. Let SN be the assumed meridian. Let BC represent any course, and AB the preceding course; also, let D and E be their middle points. Draw EH, DG, and CM, perpendicular to the assumed meridian NS. Draw also AI, EK, and BL, parallel to NS. Then $2DG$ is the double meridian distance of the course BC, and $2EH = 2KG$, is the double meridian distance of the course AB.

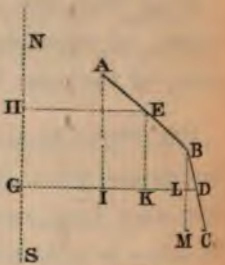


Fig. 70.

Now, $2DG = 2GK + 2KL + 2LD$; but $2KL = IL$ is the departure of the course AB, and $2LD = MC$ is the departure of the course BC; consequently,

$$2GD = 2GK + IL + MC;$$

hence, the double meridian distance of a course is equal to the double meridian distance of the preceding course, plus the departure of that course, plus the departure of the course itself: if there is no preceding course, the first two terms become zero. We therefore have the following

RULE.—I. *The double meridian distance of the first course is equal to its departure:*

II. *The double meridian distance of the second course is equal to the double meridian distance of the first course, plus its departure, plus the departure of the second course:*

III. *The double meridian distance of any course is equal to the double meridian distance of the preceding course; plus its departure, plus the departure of the course itself.*

NOTE.—It should be recollected that *plus* is here used in its algebraic sense, and that, when the double meridian distance of a course, and the departure which is to be *added* to it, are of different names, that is, one east and the other west, they will have contrary algebraic signs; hence, their algebraic sum will be expressed by their numerical difference, with the sign of the greater prefixed.

If the assumed meridian cuts the enclosure, the double meridian distances estimated to the east are plus, and those on the west must be taken with the *minus* sign.

The double meridian distance of the last course should be equal to the departure of that course. A verification of the work is therefore obtained, by comparing this double meridian distance with that departure.

AREA.

136. Let us resume the example of Art. **115**. We will first write the differences of latitude and the double meridian distances of the courses, in the following table:

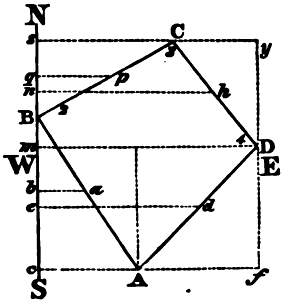


FIG. 71.

Stations.	Dif. of Latitude.	D. M. D.	Area. +	Area. −
A	$+ cB$	$+ 2ba$	$2cAB$	
B	$+ Bs$	$+ 2qp$	$2BsC$	
C	$- Dy$	$+ 2nh$		$2msCD$
D	$- Df$	$+ 2ed$		$2cmDA$

It is evident, that cB multiplied by $2ba$, or cA, will give double the area of the triangle cAB. But cB and ba are both

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plus; hence, the product will be plus, and must be put in the column of plus areas. Double the area of the triangle *BsC*, is equal to *Bs* multiplied by *2qp*, which product is also plus.

The area of the trapezoid *msCD* is equal to *yD*, or *ms*, multiplied by *nh* (Geom., Bk. IV, Prop. VII); hence, double the area is equal to *yD* into *2nh*. But since *yD* (being a southing) is minus, and *2nh* plus, it follows that the product will be negative; hence, it must be placed in the column of negative areas.

Double the area of the trapezoid *cADm*, is equal to *Df*, or *mc*, multiplied by *2de*; but, since *Df* is negative and *2de* positive, the product will be negative.

It is now evident that the difference between the two columns is equal to twice the contents of the figure *ABCD*; and since the same may be shown for any other figure, we have, for finding the areas, the following general

RULE.—I. *Multiply the double meridian distance of each course by its northing or southing, observing that like signs in the multiplicand and multiplier give plus in the product, and that unlike signs give minus in the product.*

II. *Place all the products which have a plus sign in one column, and all the products which have a minus sign in another.*

III. *Add the columns separately and take the difference of their sums; this difference will be double the area of the land.*

NOTE.—When offsets are measured, the figures of which the offsets are bounding lines are, practically, triangles and trapezoids, and the areas of these are to be separately computed, and added to or subtracted from, as the case may be, the area obtained by the foregoing rule.

137. We will now make the calculations of this example, in numbers, from the field-notes, which are the following:

Stations.	Bearings.	Distances.	Diff. Lat.	Dep.	D. M. D.
A	N 31½° W	10.40	+8.86	−5.44	+18.02 −7.14 −5.44 + 5.44
*B	N 62° E	9.20	+4.31	+8.12	+ 8.12
C	S 36° E	7.60	−6.15	+4.46	+8.12 +4.46 +20.70
D	S 45½° W	10.	−7.02	−7.14	4.46 −7.14 +18.02

We see, from inspecting the notes, that *B* is the most westerly, and *D* the most easterly station. Either of them may, therefore, be taken for the principal station. Let us assume *B* for the principal station, through which the assumed meridian passes, and distinguish it by a star, thus *.

Having done so, we enter the departure 8.12 in the column of double meridian distances, which is the double meridian distance of the course from *B* to *C*. The double meridian distances of the other courses are calculated according to the rule; and as the last, which is that of the course from *A* to *B*, is equal to the departure of that course, the work is known to be right.

Let us now form a new table, which will complete the arithmetical part of the work.

Sta.	Bearings.	Dist.	Dif. Lat.	D. M. D.	Area. +	Area. —
A	N 31½° W	10.40	+8.86	+ 5.44	48.1984	
*B	N 62° E	9.20	+4.31	+ 8.12	34.9972	
C	S 36° E	9.60	−6.15	+20.70		127.3050
D	S 45½° W	10.	−7.02	+18.02		126.5004
					83.1956	253.8054
						83.1956
					2)	170.6098

Area in sq. ch. 85.3049

Ans. 8 *A.* 2 *R.* 4.88 *P.*

PLOTTING.

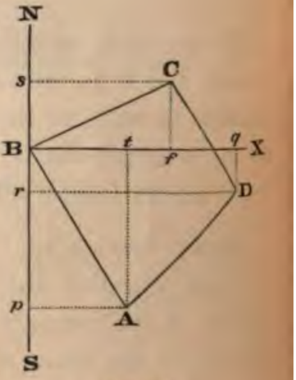

FIG. 72.

138. To make a plot of the ground, draw any line, as *NS*, to represent the meridian passing through the principal station; and on this line take any point, as *B*, to represent that station. Beginning at *B*, take the algebraic sum of the balanced latitudes and, also, of the balanced departures of the stations following. These sums are, respectively, the total latitudes and total departures (or longitudes, see Art. **148**, Note) of the several courses with respect to the principal station, *B*. Tabulate the results (see example, p. 94) as shown in the margin. Through *B*, draw *BX* (Fig. 72) perpendicular to *NS*. On *NS* lay off (*upward* since 4.31 is *plus*) *Bs* equal to 4.31 units of the scale on which the

Sta.	Total lat. from *B*.	Total dep. from *B*.
*B	0.00	0.00
C	4.31	8.12
D	−1.84	12.58
A	−8.86	5.44

plot is to be made; and on BX lay off (to the *right* since 8.12 is *plus*) Bf equal to 8.12 units of the scale. From s, as a centre, with Bf, or 8.12, as a radius, describe an arc; and from f, as a centre, with Bs, or 4.31, as a radius, describe an arc; the intersection of these arcs will be the position on the paper of Station C. On NS lay off (*downward* since 1.84 is *minus*) Br equal to 1.84 units; and on BX lay off to the right Bq equal to 12.58 units. From r, as a centre, with Bq, or 12.58, as a radius, describe an arc; and from q, as a centre, with Br, or -1.84, as a radius, describe an arc; the intersection of these arcs will be the position on the paper of Station D. Determine, in like manner, the position on the paper of each successive station; connect the points so determined by straight lines, and a complete plot of the ground will be obtained. As a check, the distances BC, CD, &c., should be measured on the plot.

139. It is convenient, but not necessary, to take the most easterly or most westerly station as the principal station. It is simply to be remembered that north latitudes and east departures are *plus*, and south latitudes and west departures are *minus;* that total latitudes and total departures are *algebraic* sums; that *plus* latitudes are to be laid off on the meridian, from the principal station, *upward*, and *minus* latitudes *downward;* that *plus* departures are to be laid off on the east and west line, from the principal station, to the *right*, and *minus* departures to the *left*.

There are, of course, other methods of plotting; but the one here given is, perhaps, the best in ease and accuracy of execution. If the latitudes and departures have been correctly balanced, and the drawing carefully made, the survey will certainly "close."

140.—EXAMPLES.

1. It is required to determine the contents and plot of a piece of land, of which the following are the field-notes, viz.:

Stations.	Bearings.	Dist.	Dif. Lat. N +	Dif. Lat. S −	Dep. E +	Dep. W −	Balanced. Lat.	Balanced. Dep.	D.M.D +	Area. +	Area. −
A	N 46½° W	20.76	14.29			15.06	+14.30	−15.04	15.04	215.0720	
B	N 51¾° E	13.80	8.54		10.84		+8.55	+10.86	10.86	92.8530	
C	E	21.35			21.35			+21.37	43.09		
D	S 56° E	27.60		15.44	22.88		−15.43	+22.90	87.36		1347.9648
E	S 33¼° W	18.80		15.72		10.31	−15.71	−10.29	99.97		1570.5287
F	N 74½° W	30.95	8.27			29.83	+8.29	−29.80	59.88	496.4062	
			31.10	31.16	55.07	55.20				804.3312	2918.4935
				31.10		55.07					804.3312
		Error . .		.06		.13	Error.				2) 2114.1623
							Ans. 105 *A.* 2 *R.* 33 *P.*				1057.08115

PLOT OF THE GROUND.

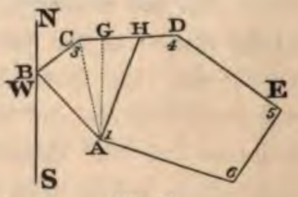

FIG. 73.

NOTE.—When the bearing is due East or due West, the error in latitude is nothing, and the corrections for latitude must be distributed among the other courses. So, when the bearing is due North or due South, the error in departure is nothing, and the error in departure must be distributed among the other courses. In the examples for practice, we have not been as careful to have as close balances as must be had in actual work on the field.

2. Required the contents and plot of a piece of land, of which the following are the field-notes.

Stations.	Bearings.	Distances.
A	S 34° W	3.95 ch.
B	S	4.60
C	S 36½° E	8.14
D	N 59½° E	3.72
E	N 25° E	6.24
F	N 16° W	3.50
G	N 65° W	8.20

Ans. 10 *A.* 0 *R.* 5 *P.*

3. Required the contents and plot of a piece of land, from the following field-notes.

Stations.	Bearings.	Distances.
A	S 40° W	70 rods.
B	N 45° W	89
C	N 36° E	125
D	N	54
E	S 81° E	186
F	S 8° W	137
G	W	130

Ans. 207 *A.* 3 *R.* 33 *P.*

4. Required the contents and plot of a piece of land, from the following notes.

Stations.	Bearings.	Distances.
A	S 40½° E	31.80 ch.
B	N 54° E	2.08
C	N 29¼° E	2.21
D	N 28¾° E	35.35
E	N 57° W	21.10
F	S 47° W	31.30

Ans. 92 *A.* 3 *R.* 32 *P.*

5. Required the area of a survey, of which the following are the field-notes.

Stations.	Bearings.	Distances.
A	N 42° E	5.00 ch.
B	East.	4.00
C	N 9° E	4 00
D	S 69° E	5.56
E	S 36° E	7.00
F	S 42° W	4.00
G	S 75° W	1 00
H	N 39° W	7.50

If, in this example, we assume A as the principal station, the double meridian distances will all be plus, and the positive area will exceed the negative.

In balancing, we shall find the error in southing to b .28 ch., and in westing .22 ch. The area is 13 *A.* 0 *R.* 11 *P.* I should, however, be remarked, that in all the examples th answers may be slightly varied by distributing the corrections.

What is the area of a survey of which the following
: field-notes? Make the plot.

Stations.	Bearings.	Distances.
A	N 75° 00′ E	54.8 rods.
B	N 20° 30′ E	41.2
C	East.	64.8
D	S 33° 30′ W	141.2
E	S 76° 00′ W	64.0
F	North.	36.0
G	S 84° 00′ W	46.4
H	N 53° 15′ W	46.4
I	N 36° 45′ E	76.8
J	N 22° 30′ E	56.0
K	S 76° 45′ E	48.0
L	S 15° 00′ W	43.4
M	S 16° 45′ W	40.5

:his survey D is the most easterly and I the most westerly
. The area is equal to 110 *A*. 2 *R*. 23 *P*. It may vary a
n account of the way in which the balancing is done.

What is the area of a survey of which the following
: notes? Make the plot.

Stations.	Bearings.	Distances.
A	S 46½° E	80 rods.
B	S 51¾° W	55.20
C	West.	85
D	N 56° W	110.40
E	N 33¼° E	75.20
F	S 74½° E	123.80

Ans. 104 *A*. 1 *R*. 16 *P*.

8. Required the area of the farm, of which the survey notes are given in Art. **123**.

Stations.	Bearings.	Distances.
A	N 68° 55′ W	31.95
B	N 8° E	1.40
C	S 87° 05′ W	22.89
D	N 30° 35′ E	8.39
E	N 42° 05′ E	23.91
F	N 87° 05′ E	14.51
G	S 64° 30′ E	7.55
H	S 71° E	12.21
I	S 27° E	17.39
K	S 30° W	16.97

Offsets between C and D to be added, 15.9450 chains.

Offsets to be subtracted, 15.1885 chains.

9. To determine the bearing and distance from one point to another, when they are so situated that one cannot be seen from the other.

Let *A* and *C* be the two points, and *AB* a meridian passing through one of them. From either of them, as *A*, measure a course *A* 2, of a convenient length in the direction toward *C*, and take the bearing with the compass. At 2, take the bearing of a second course, and measure the distance to 3. At 3, take a third bearing and measure to 4. At 4, take the bearing to *C*, and measure the distance from 4 to *C*.

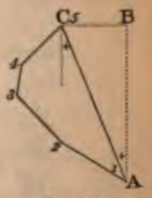

Fig. 74.

Then, the difference between the sum of the northings and sum of the southings will be denoted by AB; and the rence between the sum of the eastings and the sum of the ings, by BC. The base AB, and the perpendicular BC of right-angled triangle ABC, are then known. The angle e base, BAC, is the bearing from A to C; or the equal nate angle at C is the bearing from C to A, and the thenuse AC, is the distance.

Iaving measured the bearings and courses on the field, a table, and find the base and perpendicular of the right-ed triangle, in numbers; after which, find the bearing and nce.

ns.	Bearings.	Distances.	N.	S.	E.	W.
	N 61° W	40 ch.	19.30			34.98
	N 42° W	41.	30.47			27.43
	N 12° E	16.10	15.75		3.35	
	N 47° E	32.50	22.16		23.77	
			$AB = 87.77$		27.12	62.41

27.12

$CB = 35.29$ ch.

To find the angle BAC, or the bearing from A to C.

Radius : tan A :: AB : BC,

AB : BC :: R : tan A;

t is, applying logarithms,

a. c.) log AB (87.77) 8.056654
log BC (35.29) 1.547652
log R . . . . 10.
log tan A 21° 54′ 12″ 9.604306

To find the distance AC.

$$\sin A \ : \ R \ :: \ BC \ : \ AC;$$

Applying logarithms,

(a. c.)	log sin A 21° 54′ 12″	0.428242
	log R	10.
	log BC (35.29)	1.547652
	log AC 94.6	1.975894

Hence, the bearing and distance are both found.

NOTE.—Had any of the courses run south, AB would have been equal to the sum of the northings, minus the sum of the southings.

141. The last problem affords an easy method of finding the bearing and length of one of the courses of a survey, when the bearings and lengths of all the others are known. It may be necessary to use this method when there are obstacles which prevent the measuring of a course, or when the bearing cannot be taken. Indeed, *two omissions* may in general be supplied by calculation. It is far better, if possible, to take all the notes on the field, and it is necessary to do so, if accuracy is required. For, when any of them are supplied by calculation, there are no tests by which the accuracy of the work can be ascertained, and all the errors of the notes affect also the parts which are supplied.

If necessary, however, the following omissions in the field-notes may be supplied by calculation, viz:

I. The bearing and the length of one course.

142. The following are the field-notes of a survey:

Stations.	Bearings.	Distances.
A	N 60° W	9.72 ch.
B	N 17¼° E	7.65
C	N 15¾° W	9.40
D	N 63¾° E	10.43
E	S 49° E	8.12
F	S 13½° E	8.45
G	S 16¾° E	6.44
H		

With the known bearings and distances, find the corresponding latitudes and departures, as in annexed table:

Stations.	Bearings.	Distances.	N.	S.	E.	W.
A	N 60° W	9.72	4.86			8.41
B	N 17¼° E	7.65	7.31		2.27	
C	N 15¾° W	9.40	9.05			2.55
D	N 63¾° E	[illegible].43	4.61		9.36	
E	S 49° E	8.12		5.33	6.13	
F	S 13½° E	8.45		8.22	1.98	
G	S 16¾° E	6.44		6.17	1.86	
H						
			25.83	19.72	21.60	10.96
			19.72		10.96	
		Deficiency in Lat. South.	6.11		10.64	Deficiency in Dep. West.

The latitude of the course *HA* in the plot (Fig. 75), must, therefore, be 6.11, and its departure 10.64; hence, in the right-angled triangle HPA,

$$PA = 6.11,$$

$$HP = 10.64;$$

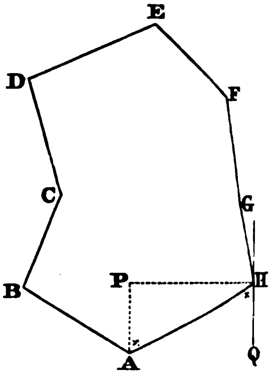

FIG. 75.

The angle PAH = angle QHA, or the bearing of the course HA.

Find PAH, as in preceding example, thus,

$$AP : PH :: R : \tan PAH;$$

that is, by logarithms,

$$\begin{aligned}
\text{(a. c.) } \log AP\ (6.11) &= 9.213959 \\
\log PH\ (10.64) &= 1.026942 \\
\log R &= 10. \\
\hline
\log \tan PAH &= 10.240901
\end{aligned}$$

Hence, PAH is 60° 8′, and since the deficiencies were in south lat. and west dep., the bearing of HA is S. 60° 8′ W.

To find the length of the course, we have,

$$\sin PAH : R :: PH \text{ [illegible] } HA;$$

that is, by logarithms,

$$\begin{aligned}
\text{(a. c.) } \log \sin PAH\ (60^\circ\ 8') &= 0.061887 \\
\log R &= 10. \\
\log PH &= 1.026942 \\
\hline
\log HA &= 1.088829
\end{aligned}$$

Hence, HA = 12.27 ch., which is the length of the required course, HA.

1. In a survey we have the following notes:

Stations.	Bearings.	Distances.
A	N 31½° W	10 ch.
B	N 62¾° E	9.25
C		
D	S 45½° W	10.40

What is the bearing and distance from station C to D?

Ans. { Bearing, S 38° 52′ E.
Distance, 7.03 ch.

2. In a survey we have the following notes:

Stations.	Bearings.	Distances.
A	S 40½° E	31.80 ch.
B	N 54° E	2.08
C		
D	N 28¾° E	35.35
E	N 57° W	21.10
F	S 47° W	31.30

What is the bearing [illegible] distance from C to D?

Ans. { Bearing, N 34° 47′ E.
Distance, 2.19 ch.

I. The bearing of one course and the length of another, when the courses are (1) contiguous; (2) separated.

143. First.—Example when the courses are contiguous. In ig. 75, let the bearing of *DE* and the length of *EF* be required, he bearings and lengths of the other courses being known.

As before, find latitudes and departures for known bearings and distances, obtaining annexed table:

Stations.	Bearings.	Distances.	N.	S.	E.	W.
A	N 60° W	9.72	4.86			8.41
B	N 17¼° E	7.65	7.31		2.27	
C	N 15¾° W	9.40	9.05			2.55
D		10.43				
E	S 49° E					
F	S 13½° E	8.45		8.22	1.98	
G	S 16¾° E	6.44		6.17	1.86	
H	S 60° 8′ W	12.27		6.11		10.64

Draw a line DF and find the bearing and the length of DF in the plot $ABCDFGH$, as in Art. **142**. The length will be found to be 15.506, and the bearing 87° 20′ 19″; the angle DFE is then equal to $87° 20' 19'' - 49°$ (the bearing of EF) $= 38° 20' 19''$; then in the triangle DEF, the sides DE (10.43), and DF (15.506), and the angle DFE (38° 20′ 19″) are known, and the angle DEF will be found from the proportion,

$$DE : DF :: \sin DFE : \sin DEF$$

to be equal to 112° 45′; hence, the bearing of DE is $112° 45' - 49° = 63° 45'$. The length of the course EF will be found from the proportion,

$$\sin DFE\,(38° 20' 19'') : \sin FDE\,(28° 54' 41'') :: DE\,(10.43) : EF$$

to be equal to 8.12.

NOTE.—In finding the angle DEF doubt arises as to the proper angle, corresponding to the logarithmic sine, to be taken; DEF may be either 67° 15′, or 112° 45′ (see Art. **39**); and hence the bearing of DE may be either 18° 15, or 63° 45′, without affecting the length of the given course DE. If the smaller angle $67^\circ\ 15'$ is taken as value of DEF, then angle FDE is $74^\circ\ 24'\ 41''$, instead of $28^\circ\ 54'\ 41''$, and the length of the required side EF, as determined from the proportion,

$$\sin DFE : \sin FDE :: DE : EF$$

will be 16.19, instead of 8.12, without affecting the given bearing.

When the length of the side EF, whose bearing is required, is not *greater* than that of the auxiliary line DF, the method given is of no service, unless some independent means exist of determining which of the two possible solutions is the one to be taken.

The following are the notes of a survey:

Stations.	Bearings.	Distances.
A	North	12.84 ch.
B	N 32° E	17.82
C	N 80° E	24.
D	S 48° E	27.
E	S 18° W	
F		46.21½

Required the length of the course EF, and the bearing of the course FA.

Length of $EF = 28.60$.

Bearing of $FA = \text{N } 73^\circ\ 28'\ 21''\text{ W}$.

144. SECOND.—Example when the courses are separated. In Fig. 75 let the bearing of AB and the length of DE be unknown.

From B, Fig. 76, one extremity of the course whose bearing is unknown, draw BP parallel and equal to DE, whose length is required. Draw then PQ and QE, equal and parallel to BC and CD, respectively; and draw PA. The lengths and bearings of

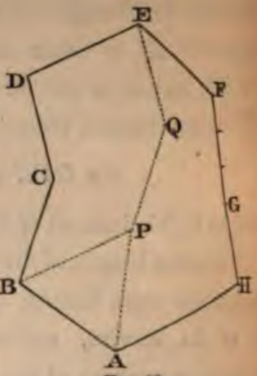

FIG. 76.

the courses PQ and QE are the same as those of BC and CD, respectively; hence, in the figure $APQEFGH$ the lengths and bearings of all the courses except AP are known; and the length and bearing of AP may be found as in Art. **142**. Then in the triangle APB, the length of AP and AB are known, and the angle APB (which is the sum or difference of the bearings of BP and AP); hence, as in Art. **143**, the length of BP or its equal DE, and the bearing of AB may be found. (Gillespie's Land Surveying, p. 299). The same doubt as to the proper solution exists here, as in the previous example.

III. The bearings of two courses when they are (1) contiguous; (2) separated.

145. FIRST.—Example when they are contiguous. In Fig. 75, let the bearings of DE and EF be unknown. Draw a line from D to F and find its length and bearing from the latitudes and departures of the other courses as before. Then in the triangle DEF the three sides are known and the three angles may be found as in Article **41**. From the angle EDF and the bearing of DF, the bearing of DE may be found; and from the angle EFD and the bearing of DF, the bearing of EF may be found.

146. SECOND.—Example when the courses are separated. Let AB and DE, Fig. 75, be the courses whose bearings are unknown. Assume the figure as in Fig. 76. Then the bearing and length of AP may be found as before. In the triangle APB, all the sides are known and the angles may be found as in the preceding article. Then the bearing of *BP*, or its parallel *DE*, may be found from the angle *BPA* and the bearing of *PA*; and the bearing of *AB*, from the angle *PAB* and the bearing of *AP* (Gillespie's Land Surveying).

IV. The lengths of two courses.

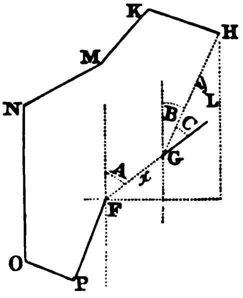

FIG 77.

147.[*] Let A = bearing of the first unmeasured course, *FG*, of the survey.

B = bearing of the second course, *GH*.

C = angle between the courses.

L = total latitude, and

D = total departure of the two unmeasured courses, obtained by computing the total latitudes and total departures of the measured courses, *HK* to *PF*, as in Art. **142**.

Let x = length of the first course.

y = length of the second course.

We shall then have,

$$L = (\text{lat. } x + \text{lat. } y) = x \cos A + y \cos B. \qquad (1)$$

$$D = (\text{dep. } x + \text{dep. } y) = x \sin A + y \sin B. \qquad (2)$$

Multiply (2) by co[illegible]

$$D \cot B = x \sin A \cot B + y \cos B. \qquad (3)$$

Subtract (3) from (1) and solve with regard to x,

$$x = \frac{L - D \cot B}{\cos A - \sin A \cot B}.$$

Multiply both numerator and denominator by sin B,

---

[*] Prof. H. S. Munroe, E.M., Ph.D., and J. Woodbridge Davis, C.E., Ph.D., in "School of Mines Quarterly," for November, 1881.

$$x = \frac{L \sin B - D \cos B}{\sin (A - B)};$$

or, substituting for $\sin (A - B)$ its value,

$$x = \frac{L \sin B - D \cos B}{\sin C}. \qquad (4)$$

In like manner we have,

$$y = \frac{D \cos A - L \sin A}{\sin C}. \qquad (5)$$

By taking into account the signs of the different quantities, the above formulas (4) and (5) will solve any case that may arise, not only when the unmeasured sides are contiguous, as in the figure, but any two sides of the polygon, *e.g.*, sides *FG* and *ON*, provided only that the courses are not parallel, or nearly so, as *FG* and *MN*.

The following table gives the proper signs in a convenient form for reference:

Signs of *L*. and *D*.	Signs of functions of *A*. and *B*.
Lat. N.; L. is +.	N.E. bearing; sin +, cos +.
Dep. E.; D. is +.	S.E. bearing; sin +, cos —.
Lat. S.; L. is —.	S.W. be[illegible]; sin —, cos —.
Dep. W.; D. is —.	N.W. b[illegible]g; sin —, cos +.

To find value of C.

$C = (A - B)$ if courses are in same or in opposite quadrants.

$C = (A + B)$ if the courses are in adjacent north or adjacent south quadrants.

$C = 180° - (A + B)$ if courses are in adjacent east quadrant
or adjacent west quadrants.

EXAMPLE.

Sta.	Bearings.	Dist.	Latitude.		Departure.	
			N.	S.	E.	W.
A	East.	48 ch.			48.00	
B	N. 71½° E.	5.18	1.64		4.91	
C	S. 13⅛° E.	34.		33.13	7.65	
D	South.	12.		12.00		
E	S. 89° 10′ W. (A)	(x)				
F	N. 80° 20′ E. (B)	(y)				
			1.64	45.13	60.56	

$$L = +43.49 \quad D = -60.56$$

From the above table we find that, in order to balance the latitude and departure columns, the total latitude of the two unknown courses must be 43.49 North, and the total departure 60.56 West. Substituting in the formulas,

$$x = \frac{43.49 \times \sin 80^\circ 20' + 60.56 \times \cos 80^\circ 20'}{\sin 8^\circ 50'};$$

$$y = \frac{60.56 \times \cos 89^\circ 10' + 43.49 \times \sin 89^\circ 10'}{\sin 8^\circ 50'}.$$

Solving, $x = 345.41$; $y = 288.91$.

As a check, the latitudes and departures of the two sides should be computed, and the survey closed as below.

Stations	Bearings.	Dist.	Latitude.		Departure.	
			N.	S.	E.	W.
A	East.	48.			48.00	
B	N. 71½° E.	5.18	1.64		4.91	
C	S. 13⅛° E.	34.		33.13	7.65	
D	South.	12.		12.00		
E	S. 89° 10′ W.	345.41		5.02		345.37
F	N. 80° 20′ E.	288.91	48.51		284.81	
			50.15	50.15	345.37	345.37

The following are the field-notes of a survey:

Stations.	Bearings.	Distances.
A	North.	7.81 ch.
B	S. 76¼° E.	
C	S. 10° 47′ W.	28.42
D	N. 84½° W.	27.12
E	N. 4½° W.	
F	East.	16.68

Required the distance from *B* to *C* and from *E* to *F*.

B to *C*, 17.87; *E* to *F*, 21.82.

148. Another Method of Determining Areas.*

The area of any right-line figure may be decomposed into a series of right trapezoids and triangles by letting fall from the vertices perpendiculars to any fixed straight line, called the **Base.**

The triangles may be considered trapezoids having one parallel side reduced to zero. Some of the trapezoids may be *subtractive;* but we may say that the *algebraic* sum of the trapezoids composing the series is the area of the figure. If the figure be bounded by a continuous or a broken curve, its area is, *approximately,* equal to that of a right-line figure whose vertices are contained in the curve. By properly locating these vertices, we may approximate the area as closely as may be required.

Area of a Series of Right Trapezoids.

Before deducing the necessary rules, a few preliminary definitions will be given.

---

* J. Woodbridge Davis, C. E., Ph. D., 1879.

The position of points in a plane may be fixed by referring them to two intersecting straight lines of the plane. The two intersecting lines are called **Coordinate Axes.**

Thus, let XX' and YY' intersect at A; the position of the point P is known when RP, its distance from YY' on a line parallel to XX', and QP, its distance from XX' on a line parallel to YY', are known. RP, or its equal AQ, is called the **Abscissa** of the point P; and QP, or its equal AR, is called the **Ordinate** of P. AQ and QP together are called the **Coordinates** of P. The point A, in which XX' and YY' intersect, is called the **Origin of Coordinates.** When XX' and YY' are perpendicular to each other, as is most convenient, the coordinates of points referred to them are called **Rectangular Coordinates.**

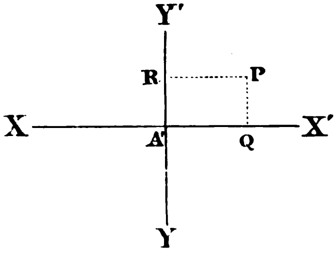

FIG. 78.

Consider any series of five right trapezoids lying consecutive, with their bases on one straight line. The area of the series, as found by ordinary method, the symbols of Fig. 79 used, is

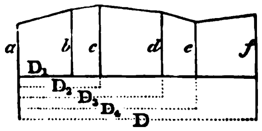

FIG. 79.

$$\tfrac{1}{2}[D_1(a+b)+(D_2-D_1)(b+c)+(D_3-D_2)(c+d)+(D_4-D_3)(d+e)+(D-D_4)(e+f)]. \qquad (1)$$

This may be transformed into

$$\tfrac{1}{2}[D_1(a-c)+D_2(b-d)+D_3(c-e)+D_4(d-f)+D(e+f)]. \qquad (2)$$

From this is derived the following rule, which is true, at l for any series of five right trapezoids arranged as in Fig. 79. For convenience let this be called Rule A.

Rule A.—To find the area bounded partly by any broken line, determined from a base line by means of rectangular ordinates, and otherwise bounded by the base line and terminal ordinates:

Multiply the distance of each intermediate ordinate from the first by the difference between the two adjacent ordinates, always subtracting the following from the preceding in order along the broken line. Also, multiply distance of last ordinate from first by the sum of last two ordinates. Divide the sum of these products by 2.

If this rule apply to a series of n trapezoids, its area is

$$\tfrac{1}{2}\,[D_1(a-c)+D_2(b-d)+\text{etc.}+D_{n-1}(i-k)+D_n(j+k)]. \quad (3)$$

Add another trapezoid to the latter end of this series. Its area is

$$\tfrac{1}{2}\,(D_{n+1}-D_n)\,(k+l). \quad (4)$$

Add this to (3). The result is the area of a series of $n+1$ trapezoids, and is expressed by the following:

$$\tfrac{1}{2}\,[D_1(a-c)+\text{etc.}+D_{n-1}(i-k)+D_n(j-l)+D_{n+1}(k+l).$$

Therefore, the rule applies to a series of $n+1$ trapezoids.

If from the series of n trapezoids the last trapezoid, whose area is

$$\tfrac{1}{2}\,(D_n-D_{n-1})\,(j+k),$$

be subtracted, the area of the remaining series of $n-1$ trapezoids is the following:

$$\tfrac{1}{2}\,[D_1(a-c)+D_2(b-d)+\text{etc.}+D_{n-1}(i+j)].$$

Therefore, the rule applies to a series of $n-1$ trapezoids.

It is certain that the rule applies to a series of five trapezoids. Let $n = 5$. Then $n+1 = 6$, and $n-1 = 4$. Consequently, the rule applies to a series of six trapezoids, and to a series of four. For this reason it applies to series of three and seven trapezoids, and so on. Because a series containing any number of trapezoids may be found by continually adding, or subtracting, one trapezoid to, or from, a series of five, and because the application of the rule is not affected by each such operation, it follows that Rule A applies to a series consisting of any number of trapezoids.

If that portion of the broken line which forms the upper side of the last trapezoid be perpendicular to base, whether directed towards it or from it, the area of the last trapezoid is zero. But expression (4), which represents this area, is zero. Therefore the rule conforms to this case. If the last portion of broken line be retrogressive, as shown in Fig. 80, where the line terminates at K_3, or K_4, the last trapezoid must be subtracted in order that the required area—*between broken line and base limited by terminal ordinates*—may be obtained. But in this case expression (4) is intrinsically negative, and therefore should, as before, be algebraically added to the preceding area. Hence the rule conforms to this case.

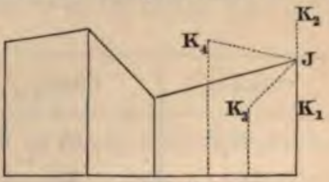

FIG. 80.

The statements of last paragraph are true, whatever the number of trapezoids in the series; even should the trapezoid added compose, alone, the series. In consequence, since every possible broken line is some succession of progressive, retrogressive, and perpendicular elements, and because the addition of each element and its accompanying trapezoid does not affect the rule, rule A, or formula (3), is perfectly general, whatever may be the complication of the broken line.

EXAMPLE.—Let it be required to determine the area of a tract of land whose description is as follows:

Beginning at a poplar on the south bank of the Cumberland river; thence south 31 poles to a stone monument; thence east 180 poles to a beech; thence north 40 poles to a sycamore on the bank of said river; thence, with the meanderings of the same, to the beginning.

It was found convenient to determine the irregular boundary by means of offsets from the long straight side. The positions and lengths of these offsets are recorded in the first two columns below. To obtain the area by Rule A, a third column of alternate differences is obtained; and in the fourth column are placed the products of corresponding quantities in first and third columns: half the algebraic sum is the area.

Distances.	Offsets.	Differences.	Products.
0	31		
15	30	—8	—120
45	39	—12	—540
77	42	0	0
86	39	—2	—172
113	44	3	339
161	36	4	644
180	40	76	13680

14663
—832
2) 13831

Square rods . . . 6915½

The advantages of this method of calculation are readily perceived by inspection of the above example, where every product except the last, is found by mental work. To illustrate this more forcibly, let us suppose the base line to be moved, for instance, 2658 poles directly south. Now, all the products except the last remain as simple, in fact the same, as before, while the last only is increased.

The old method of calculation would now require every product to be increased.

If, to find the area of an irregular figure, parallel cross measurements be made at appropriate places, intersecting a given base line at known points, the figure may be considered a series of trapezoids. If the base line be perpendicular to the direction of cross-measurements, Rule A obviously applies. If the base line be inclined to the cross lines, *Rule A may be applied, but the final result must be multiplied by the sine of the angle of inclination.*

EXAMPLES.

1. Wallace Colyar agrees to sell to James Beckwith at ninety dollars per acre, a piece of unimproved bottom land, lying between the west bank of the Delaware river and the foot of the adjacent hill. The description of the survey is as follows:

Beginning at a willow on the west bank of Delaware river, this being the northeast corner of Henry Gillespie's home place; thence with the meanderings of the bank of the river—[numerous courses here omitted]—to a white oak, the corner of James Beckwith's land; thence west with his south boundary to a spring at the foot of the hill; thence meandering with the foot of the hill—[numerous courses omitted]—to a black walnut, Henry Gillespie's northwest corner; thence, with his line east to the beginning. The east and west being sinuous but unchangeable natural boundaries, it is only required to determine, as easily and accurately as possible, the area. Accordingly, a line is run due north through the land and cross-widths are taken at right angles. The distances on base line and the lengths of cross lines are recorded in the columns below. It is required to find the area in acres and the sum in dollars to be paid for the strips of land.

Distances.	Widths.
0	38 rods.
19	29
40	32
78	36
111	51
145	45
173	40
200	44
228	50
254	55
290	58
337	43

Ans. 94.05625 acres; $8465.06.

2. Caleb Hopkins employs John Bryant to cut and burn the underbrush in an irregular piece of hilly woodland, at one dollar and a half per acre, the agreement being that the chain shall be allowed to rest upon the surface throughout its length, and not be stretched horizontally.

A base line was run N. 20° W. through the land, and cross-measurements were taken in directions due east and west. The distances in base line and the lengths of cross lines are as follows:

Distances.	Widths.
0	0 rods.
10	19
26	41
55	49
78	52
106	61
129	50
153	55
175	39
180	45
194	31
209	0

To find the Area of a Polygon.

It has been proved that Rule A is true for any series of trapezoids, whatever may be the complication of the broken line which forms the upper sides of the right trapezoids; therefore the rule is true when the broken line returns to its point of beginning. But in this case the area required as the rule is the area enclosed by the broken line itself, or is the area of any polygon. Now D, the distance between first and last ordinates, becomes zero, causing the only term, which depends upon a sum of two ordinates for one factor, to disappear.

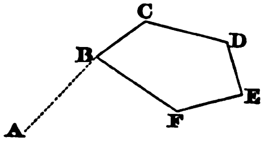

FIG. 81.

To treat this case in the most general way, suppose B, C, D, E, F (Fig. 81), to be points anywhere situated in a plane, and referred in position by rectangular co-ordinates to any point A in same plane; and suppose points to be connected in the order named by a broken line, ending again at B. Let the ordinates of the points be denoted by a, b, c, d, e, f, and the abscissas by a', b', c', d', e', f'. Connect the origin by a straight line with any of the points, as B. Then the area of the polygon $ABCDEFBA$, which is equal to the area of the polygon $BCDEFB$, is by Rule A,

$$\tfrac{1}{2}\,[b'(a-c)+c'(b-d)+d'(c-e)+e'(d-f)+f'(e-b) \\ +b'(f-a)] \qquad (5)$$

$$=\tfrac{1}{2}\,[b'(f-c)+c'(b-d)+d'(c-e)+e'(d-b) \\ +f'(e-b)] \qquad (6)$$

$$=-\tfrac{1}{2}\,[b(f'-c')+c(b'-d')+d(c'-e')+e(d'-f') \\ +f(e'-b')]. \qquad (7)$$

From expressions (6) (7) can be framed the following rule:

RULE B.—To find the area of any polygon whose vertices are fixed by rectangular co-ordinate measurements:

Multiply the abscissa of each vertex by the difference between the ordinates of the two adjacent vertices; or, multiply the ordinate of each vertex by the difference between the abscissas of the two adjacent vertices; always making the subtraction in the same direction around the polygon. Half the sum of these products is the area.

If the origin be placed at a vertex, one term vanishes whichever way the rule is used. If one of the co-ordinate axes be passed through two vertices, two terms vanish, when the rule is used one way

The determination of the areas of polygons is a problem of requent occurrence in all branches of engineering and many ther professions. Rule B is invariably simpler than the rdinary formula for this case, and is therefore presented above n the most general terms. If for words, *abscissa, ordinate, vertex,* in Rule B, be substituted *longitude, latitude, station,* that rule applies technically to the case of land surveys.

Example.—Recently a survey of a tract of one hundred and fifty square miles of coal land in Tennessee was made on the co-ordinate system; that is, every corner of the old grants, of the subsequent sales out of them, and of the older adverse claims within them, and every station of a road or other traverse, as well as all important points, as coal mines, outcrops, bridges, crossroads, springs, villages, etc., etc., was fixed in position with respect to an assumed point, by means of rectangular co-ordinates directed due north and east. Thus, any parcel of land could be easily plotted, when wanted, in any of the geological or other maps; while merely a glance at the table served to indicate its position in the district. When the area of such a piece was required, it was only necessary to proceed as in the following example:

Station.	Total latitude.	Total longitude.	Difference between alternate longitudes.	Double areas.
A	7087 ft.	94851 ft.	+1201	8511487
B	10020	97403	−6518	−65310360
C	8181	101369	−5752	−47057112
D	5012	103155	+2765	13858180
E	2873	98604	+8304	23857392

Area in sq. ft. $= \frac{66140413}{2}$

If the latitudes were larger than longitudes, differences of latitudes should be made the factors with total longitudes.

NOTE.—The *total latitude* of a station with respect to any assumed point, is the distance, measured on a meridian through the assumed point, from the point to the foot of a perpendicular drawn from the station to the meridian; and the *total longitude* is the distance of the station from the meridian through the assumed point.

To find the area of a polygon surveyed, from the field notes of the bearings and distances of its sides.

After finding the latitude and departure of each course and balancing the survey, as already explained, make a column of total latitudes of the various stations referred to any one of them as origin. This selection of origin reduces one double area product to zero. Now, instead of calculating the total longitudes of all stations and finding the differences between alternate ones, according to Rule B in formula (7), we may obtain the same result in simpler manner by adding the departures of each pair of adjacent courses. Modified in this way the operation becomes governed by the following rule:

RULE C.—*Multiply the total latitude of each station by the sum of the departures of the two adjacent courses. The algebraic half sum of these products is the area.*

EXAMPLE.

Stations.	Bearing.	Distance.	Latitude.		Departure.		Total Latitude.	Adjacent Departures.	Double Areas.
			N +	S −	E +	W −			
A	N 35° 00′ E	2.70	2.21		1.55				
B	N 83° 30′ E	1.29	.15		1.28		2.21	2.83	6.2543
C	S 57° 00′ E	2.22		1.21	1.86		2.36	3.14	7.4104
D	S 34° 15′ W	3.55		2.93		2.00	1.15	−0.14	−0.1610
E	N 56° 30′ W	3.23	1.78			2.69	−1.78	−4.69	8.3482

2) 21.8519

Square chains . . . 10.9253

To find the *total latitude* of each station, add to total latitude of preceding station the latitude of preceding course. If the latitude of last station, found in this way, be equal to the latitude of last course with reversed sign, the work is correct. However, the latitude of first station, or station taken as origin, is always zero; of last station it is always the latitude of last course with reversed sign; and of second station it is always the latitude of first course. To find the *adjacent departures*, add the departures of the two courses, one on each side of the station.

SECTION V.

MAGNETIC DECLINATION OR VARIATION OF THE NEEDLE.

The following articles, **149–164**, are essentially, and so far as practicable *verbatim*, from papers of the U. S. Coast and Geodetic Survey.

149. The magnetic declination at any place is the angle which the compass-needle, when it is correctly constructed and freely suspended, makes with the true meridian. The true meridian is fixed, but the declination varies because the direction in which the needle points is in a continuous state of change. Therefore, whenever a measure of the declination of the needle is taken, the exact time (year, day of month, and hour of the observations) should be recorded as well as the geographical position of the place, or its latitude and longitude expressed to the nearest minutes of arc.

150. The declination is called "West" when the north end of the needle points to the west of the true meridian, and it is called "East" when the north end of the needle points east of the true meridian. In order to give an idea of the amount of the declination at present observable within the limits of the United States we instance the following places at or near which it reaches extreme value, which are given to the nearest whole degree (1878):

At Eastport, Me., declination 18° west.
At the mouth of the Rio Grande, Texas, 8° east.
At San Diego, Cal., 14° east.
At Sitka, Alaska, 29° east.
At Fort Yukon, Alaska, 36° east.

151. The accuracy with which the declination may be determined depends chiefly upon the instrumental means, but also, and in a great measure, upon the care taken in the use of the instruments and the selection of the proper methods and times for observing.

Omitting any detailed notice of the irregular variations to which the magnetic needle is subject, it becomes important for the purposes of the surveyor to refer particularly to the changes which have a special bearing upon his observations. These are the *daily variation* and the *secular variation.*

152. The Daily Variation.—It has been found that at about the time of sunrise the north end of the needle has a slow motion towards the east which soon ceases. The needle is then said to be at its eastern elongation; its north end then begins a retrograde motion towards the west, and at about one o'clock in the afternoon reaches the point at which it is said to be at its western elongation, after which it again turns back towards the east.

The times at which the needle reaches its eastern and western elongations vary with the seasons of the year (with the sun's declination), happening a little earlier in summer than in winter.

The angular range between the eastern and western elongations varies also with the season of the year.

The average position of the needle for the day is called the *mean magnetic meridian.*

At about six o'clock in the evening (and for about an hour before and after), throughout the year, the position of the needle coincides very nearly with the mean magnetic meridian, and this, therefore, is the time most favorable for making observations to obtain at once the mean declination.

153. For reducing the direction of the needle observed at other hours to the mean magnetic meridian the following table is furnished. It gives to the nearest minute the variations of the needle from its average position during the day, for each hour in the day for the four seasons of the year.

Table for reducing the observed declination to the mean declination of the day.

	The needle points east of the mean magnetic meridian.					The needle points west of the mean magnetic meridian.							
	A.M.	A.M.	A.M.	A.M.	A.M.	A.M.	Noon.	P.M.	P.M	P.M.	P.M.	P.M.	P.M.
	h.	h.	h.	h.	h.	h.	Noon.	h.	h.	h.	h.	h.	h.
Hour........	6	7	8	9	10	11		1	2	3	4	5	6
	′	′	′	′	′	′	′	′	′	′	′	′	′
Spring.....	3	4	4	3	1	1	4	5	5	4	3	2	1
Summer....	4	5	5	4	1	2	4	6	5	4	3	2	1
Autumn....	2	3	3	2	0	2	3	4	3	2	1	1	0
Winter....	1	1	2	2	1	0	2	3	3	2	1	1	0

154. It appears from observations of the daily fluctuation of the declination that the mean of the extreme easterly and westerly positions in any one day approaches nearly (within half a minute) to the mean position of the day, as derived from hourly observations continued day and night. Since corrections to observed declinations to refer them to the mean of the day are generally very unsatisfactory, it is recommended to observe the declination for any one day at the epochs of the eastern magnetic elongation and of the western magnetic elongation and to take the mean position as representing the declination for that day. The epochs of extreme positions, as observed at Philadelphia, Washington, and Key West, apply, with comparatively small changes, to nearly all places within the United States and may be stated to be as follows: Referring to the north end of the magnet, the morning *eastern* elongation occurs, on the average, from May to September, inclusive, about 7½ A.M.; in March, April, and October, about 8 A.M.; in November, about 8½ A.M., and in December, January, and February, about 9 A.M.; earliest time in August, about 7¼ A.M.; latest in January, about 9 A.M. These epochs, however, are subject to great fluctuations and cannot be depended upon in any one case within one hour and frequently they cannot be recognized at all, either on account of the small range of the daily fluctuation—the amount of which in winter is but one-half, nearly, of the amount in summer—which is easily disguised by small irregularities, or on account of disturbances, which reach their maxima in September and October, and generally are more predominant in winter than in summer. The afternoon *western* elongation occurs, on the average, about 1¼ P.M. from May to November, inclusive, and about 1¾ P.M. in the remaining months; also, earliest in September—some minutes before 1 P.M.—and latest in January, about 1¾ P.M. The afternoon epoch is subject to *less* fluctuation than the morning epoch.

155. The Secular Variation of the magnetic declination is a subject of the greatest importance to surveyors. It manifests itself by a gradual change in one direction, which at first increases slowly, then more rapidly, diminishing again afterward until the needle becomes stationary and subsequently returns by similar changes to its former position, the whole period extending over nearly two and a half centuries. Thus, at Philadelphia the declination was 8¾° west in 1700, whence it diminished until in 1800 it reached a minimum 2°.1 (2° 6′), and increased again to 6°.8 in 1880. At present all along the Atlantic and Gulf coasts the effect of the secular variation is to *increase* west declinations or to *decrease* east declinations by from 2′ to 5′, but on the Pacific coast the effect is opposite in direction, viz., *increasing* east declinations by from 1′ to 3′. In Alaska, however, there are indications of a decrease of east declination.

156. Lying between the region in which the variation of the needle is west and that in which such variation is east, is a line of *no variation*, on which the magnetic meridian coincides with the true meridian.

The north (or seeking) end of the needle always inclines toward the *line of no variation:* hence, for all points east of this line, the variation is *West;* and for all points west of it, the variation is *East.*

This line is not a fixed line, but changes its position from year to year. By referring to a map, such line for the United States may be traced. In 1870, it crossed Sault St. Marie at the lower end of Lake Superior, passed, very nearly, through Cleveland in the State of Ohio, Raleigh in North Carolina, and passed into the Atlantic Ocean near Wilmington, North Carolina. In 1875, it crossed Lake Superior and entered Michigan at White Fish Point, passed thence, very nearly, through Bay City Michigan, Oberlin Ohio, Parkersburgh West Virginia, thence, with a slight curve to the southwest, to Fayetteville North Carolina, and thence into the Atlantic Ocean a little to the west of Cape Fear. The line of no variation is now moving quite rapidly to the south and west, and therefore it is that *west* declinations of the needle are increasing, and *east* declinations decreasing.

157. The U. S. Coast and Geodetic Survey has made a collection of magnetic declinations observed at various places in the United States and elsewhere. Mr. Charles A. Schott, chief of the Computing Division of the Survey, has tabulated the observed declinations, and deduced from them a Table of Formulæ. This table is here given so far as it relates to localities in the United States. The localities are arranged geographically, as far as practicable, and their positions are given by latitude and longitude (west of Greenwich).

Formulæ expressing the magnetic declination at various places in the United States.

Locality.	Latitude.	Longitude.	Expression for Magnetic Declination.
	° ′	° ′	° ° °
Portland, Me.	43 38.8	70 16.6	$D=+10.72+2.68\sin(1.33\,m+24.1)$.
Burlington, Vt.	44 28.2	73 12.3	$D=+10.81+3.65\sin(1.30\,m-20.5)$ $+0.18\sin(7.0\,m+132)$.
Rutland, Vt.	43 36.5	72 55.5	$D=+10.08+3.82\sin(1.5\,m-24.3)$.
Portsmouth, N. H.	43 04.8	70 48.0	$D=+10.63+3.17\sin(1.44\,m-4.7)$.
Newburyport, Mass.	42 48.4	70 49.0	$D=+10.07+3.10\sin(1.4\,m+1.9)$.
Salem, Mass.	42 31.9	70 52.5	$D=+9.80+3.61\sin(1.50\,m-1.0)$.
Boston, Mass	42 21.5	71 03.8	$D=+9.52+2.93\sin(1.30\,m+5.0)$.
Cambridge Mass.	42 22.9	71 07.7	$D=+9.58+2.69\sin(1.3\,m+7.0)$ $+0.18\sin(3.2\,m+44)$.
Nantucket [illegible]	[illegible] 17.0	70 06.0	$D=+9.29+2.78\sin(1.25\,m+5.5)$.
Provide [illegible]	[illegible] 49.5	71 24.1	$D=+9.13+2.99\sin(1.45\,m-3.4)$ $+0.19\sin(7.2\,m+116)$.
Ha [illegible]	[illegible] 45.9	72 40.4	$D=+8.06+2.90\sin(1.25\,m-26.4)$.
N [illegible]	[illegible] 18.5	72 55.7	$D=+7.78+3.11\sin(1.40\,m-22.1)$.

Locality.	Latitude.		Longitude.		Expression for Magnetic Declination.
	°	′	°	′	
Albany, N. Y	42	39.2	73	45.8	$D = +\ 8.17 + 3.02 \sin (1.44\,m - 8.3)$.
Oxford, N. Y.........	42	26.5	75	40.5	$D = +\ 6.19 + 3.24 \sin (1.35\,m - 18.9)$.
Buffalo, N. Y.........	42	53.8	78	53.5	$D = +\ 3.66 + 3.47 \sin (1.4\,m - 27.8)$.
Erie, Pa.....	42	07.8	80	05.4	$D = +\ 2.26 + 2.71 \sin (1.55\,m - 29.7)$.
Cleveland, Ohio......	41	30.3	81	42.0	$D = +\ 0.10 + 2.07 \sin (1.40\,m - 6.2)$.
Detroit, Mich	42	20.0	83	03.0	$D = -\ 0.97 + 2.21 \sin (1.50\,m - 15.8)$.
Saint Louis, Mo......	38	38.0	90	12.2	$D = -\ 7.15 + 2.33 \sin (1.4\,m - 20.1)$.*
New York, N. Y.....	40	42.7	74	00.0	$D = +\ 6.40 + 2.29 \sin (1.6\,m - 5.5)$ $+ 0.14 \sin (6.8\,m + 64)$.
Hatborough, Pa......	40	12	75	07	$D = +\ 5.23 + 3.28 \sin (1.54\,m - 18.2)$ $+ 0.22 \sin (4.1\,m + 157)$.
Philadelphia, Pa.....	39	56.9	75	09.0	$D = +\ 5.38 + 3.29 \sin (1.55\,m - 23.9)$ $+ 0.39 \sin (4.0\,m + 161)$.
Harrisburg, Pa.......	40	15.9	76	52.9	$D = +\ 2.93 + 2.98 \sin (1.50\,m + 0.2)$.
Baltimore, Md.......	39	17.8	76	37.0	$D = +\ 3.20 + 2.57 \sin (1.45\,m - 21.2)$.
Washington, D. C....	38	53.3	77	00.6	$D = +\ 2.47 + 2.47 \sin (1.40\,m - 14.6)$.
Cape Henry, Va......	36	55.5	76	00.5	$D = +\ 2.54 + 2.41 \sin (1.50\,m - 35.4)$.
Charleston, S. C.....	32	46.6	79	55.8	$D = -\ 2.14 + 2.74 \sin (1.35\,m - 1.3)$.
Savannah, Ga	32	04.9	81	05.5	$D = -\ 2.54 + 2.32 \sin (1.5\,m - 28.6)$.
Key West, Fla........	24	33.5	81	48.5	$D = -\ 3.90 + 2.98 \sin (1.4\,m - 33.5)$.
Mobile, Ala..........	30	41.4	88	02.5	$D = -\ 4.49 + 2.66 \sin (1.45\,m - 76.4)$.
New Orleans, La.....	29	57.2	90	03.9	$D = -\ 5.61 + 2.57 \sin (1.4\,m - 61.9)$.
San Diego, Cal.......	32	42.1	117	14.3	$D = -12.54 + 1.64 \sin (1.2\,m - 180.0)$.
Monterey, Cal	36	36.1	121	53.6	$D = -12.82 + 3.54 \sin (1.0\,m - 142.9)$.
San Francisco, Cal...	37	47.5	122	27.2	$D = -13.34 + 3.23 \sin (1.00\,m - 130.3)$.
Cape Disappointment, Wash. Ter........	46	16.7	124	02.0	$D = -20.72 + 2.81 \sin (1.2\,m - 188.8)$.
Sitka, Alaska........	57	02.9	135	19.7	$D = -26.72 + 2.41 \sin (1.6\,m - 107.1)$.
Unalashka, Alaska...	53	52.6	166	31.5	$D = -18.34 + 1.45 \sin (1.4\,m - 67.8)$.

158. The epoch to which the formulæ refer is 1850; hence, in the "expression for magnetic declination,"

$$m = t - 1850.$$

To illustrate the use of the table. Let it be required to find the declination of the needle at Albany, N. Y., in August, 1879, or 1879.6.

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* Approximate expression.

The tabular expression for magnetic declination at Albany is

$$D = +8^\circ.17 + 3^\circ.02 \sin (1.44^\circ\, m - 8^\circ.3).$$

$$m = 1879.6 - 1850 = 29.6.$$

$$1.44^\circ\, m = 42^\circ.624.$$

$$\therefore\ 1.44^\circ\, m - 8^\circ.3 = 34^\circ.324.$$

$$\text{Natural } \sin (34^\circ.324) = .5638\,;$$

hence, $$D = +8^\circ.17 + 3^\circ.02 \times .5638 = +9^\circ.87\,;$$

which gives the computed declination of the needle at Albany in 1879.6, as 9°.87 (*west*, since the result is *plus*), which differs from the observed declination at that time but one-hundredth of a degree.

If the time for which the declination is desired is prior to 1850, then m will be *negative.* For example, let the declination at Albany for 1836.8 be required; then

$$m = 1836.8 - 1850 = -13.2,$$

and $$1^\circ.44\, m = 1^\circ.44 \times (-13.2) = -19^\circ.008,$$

and $$1^\circ.44\, m - 8^\circ.3 = -27^\circ.308,$$

and $$\sin (-27^\circ.308) = -.45877\,;$$

$$\therefore\ D = 8^\circ.17 + 3^\circ.02 \sin (-27^\circ.308) = 8^\circ.17 - 1^\circ.39 = +6^\circ.78\,;$$

which agrees exactly with the observed declination.

The student is referred to Mr. Schott's paper, Appendix No. 9, U. S. Coast and Geodetic Survey Report for 1879, for valuable tables of Magnetic Declinations.

159. From the same paper is taken the following table of computed *annual changes* in the declination of the magnetic needle for 1870, 1880, and 1885, expressed in minutes of arc, a + sign indicating north end of needle moving westward, a − sign indicating north end moving eastward:

TABLE.

Locality.	Annual change.		
	In 1870.	In 1880.	In 1885.
	′	′	′
Portland, Me.	+2.4	+1.6	+1.2
Burlington, Vt.	+5.0	+6.0	+5.8
Rutland, Vt.	+6.0	+5.6	+5.3
Portsmouth, N. H.	+4.4	+3.7	+3.3
Newburyport, Mass.	+3.9	+3.3	+2.9
Salem, Mass.	+5.0	+4.1	+3.5
Boston, Mass.	+3.4	+2.9	+2.5
Cambridge, Mass.	+2.9	+2.1	+1.8
Nantucket, Mass.	+3.3	+2.7	+2.4
Providence, R. I.	+3.8		
Hartford, Conn.	+3.8	+3.7	+3.6
New Haven, Conn.	+4.6	+4.3	+4.1
Albany, N. Y.	+4.3	+3.7	+3.4
Oxford, N. Y.	+4.5	+4.3	+4.0
Buffalo, N. Y.	+5.1	+5.0	+4.8
Erie, Pa.	+4.4	+4.2	+4.0
Cleveland, Ohio.	+2.8	+2.5	+2.2
Detroit, Mich.	+3.4	+3.0	+2.8
Saint Louis, Mo.	+3.4	+3.2	+3.0
New York, N. Y.	+2.4	+2.5	+2.6
Hatborough, Pa.	+4.6	+4.5	
Philadelphia, Pa.	+4.9	+4.9	+5.3
Harrisburg, Pa.	+4.1	+3.3	+2.8
Baltimore, Md.	+3.9	+3.6	+3.2
Washington, D. C.	+3.5	+3.2	+3.0
Cape Henry, Va.	+3.8	+3.7	+3.6
Charleston, S. C.	+3.5	+3.0	+2.7

Locality.	Annual change.		
	In 1870.	In 1880.	In 1885.
	′	′	′
Savannah, Ga.	+3.6	+3.5	+3.3
Key West, Fla.	+4.3	+4.2	+4.1
Mobile, Ala.	+2.8	+3.4	+3.7
New Orleans, La.	+3.1	+3.5	+3.7
San Diego, Cal.	−1.9	−1.7	−1.6
Monterey, Cal.	−2.0	−1.5	−1.1
San Francisco, Cal.	−1.0	−0.5	−0.3
Cape Disappointment, W. Ter.	−3.4	−3.1	−2.7
Sitka, Alaska.	+1.0	+2.1	+2.5
Unalashka, Alaska.	+1.6	+1.9	+2.0

160. It will be observed that the amount of change is by no means the same, even in places not far remote from each other, as New York and Philadelphia.

In grouping together a table of the present rate of change, much allowance must therefore be made for possible local peculiarities that have not been ascertained.

A surveyor should, at the time and place of survey, determine the true meridian and thence the magnetic declination for record with his survey.

Method of ascertaining the Declination.

161. The best practical method of determining the true meridian of a place, is by observing the north star, Polaris. If this star were precisely at the point in which the axis of the earth prolonged pierces the heavens, then the intersection of the vertical plane passing through it and the place, with the surface of the earth, would be the true meridian. But the star being at a distance from the pole equal to 1° 30′ nearly, it performs a revolution about the pole in a circle, the polar distance of which is 1° 30′ nearly, and the time of revolution is 23 hours and 56 minutes.

To the eye of an observer this star is continually in motion, and is due north but twice in 23 hours and 56 minutes, and is then said to be on the meridian. When it departs from the meridian, it apparently moves east or west for 5 hours and 59 minutes, and then returns to the meridian again. When at its greatest distance from the meridian, east or west, it is said to be at its greatest *eastern* or *western* elongation.

162. The western elongations from the beginning of April to the end of September, and the eastern from the beginning of October to the end of March occur in the day-time. If it be necessary to determine the meridian at that particular season of the year, and at night, let 5 hours and 59 minutes be added to or subtracted from the time of greatest eastern or western elongation, and the observation be made at night when the star is on the meridian.

163. The angle which the meridian plane makes with the vertical plane passing through the pole-star when at its greatest eastern or western elongation, is called the **Azimuth of Polaris.**

The following extract, Art. **164**, with the tables, is from the Report of the U. S. Coast and Geodetic Survey for 1881:

164. The following tables of the times and azimuths of Polaris *when at elongation* have been prepared for the benefit of those surveyors and others who may prefer to make use of the pole-star for their determination of the true meridian, and whose instrumental outfit for the measure of the declination may be limited to a compass with sights or to a small theodolite with compass-needle attached, and who may be without a chronometer.

The method was recommended to surveyors by Dr. Charles Davies in the revised edition of his work on surveying, and a description of it still forms part of the instructions of the Commissioner of the General Land Office to the surveyors-general of public land of the United States (editions of 1855, 1871, and 1878). The tables given in these instructions have either become obsolete from lapse of time or are not sufficiently extended for future use. They were, therefore, recomputed, and in their present form and with the rules given for interpolation will be found to possess greater accuracy than any similar tables previously published. The tables include all elongations whether occurring by day or night. Polaris may be observed in day-time when the sun is not too high even with moderately powerful telescopes; besides, a complete table facilitates interpolation.

Mean local time (astronomical, counting from noon) of the elongations of Polaris.

[The table answers directly for the year 1885, for latitude +40° and for longitude 6 hours west of Greenwich.]

Date.		Eastern elongation.		Western elongation.	
		h.	m.	h.	m.
Jan.	1	0	35.3	12	24.6
"	15	23	36.1	11	29.3
Feb.	1	22	29.0	10	22.2
"	15	21	33.7	9	27.0
Mar.	1	20	38.5	8	31.8
"	15	19	43.4	7	36.6
Apr.	1	18	36.4	6	29.7
"	15	17	41.4	5	34.7
May	1	16	38.6	4	31.8
"	15	15	43·7	3	36.9
June	1	14	37.1	2	30.3
"	15	13	42.2	1	35.4

Date.		Eastern elongation.		Western elongation.	
		h.	m.	h.	m.
July	1	12	39 6	0	32.8
"	15	11	44.7	23	34.0
Aug.	1	10	38.2	22	27.5
"	15	9	43.3	21	32.6
Sept.	1	8	36.7	20	26.0
"	15	7	41.7	19	31.1
Oct.	1	6	38.9	18	28.2
"	15	5	43.9	17	33.2
Nov.	1	4	37.0	16	26.4
"	15	3	41.9	15	31.3
Dec.	1	2	38.9	14	28.2
"	15	1	43.6	13	33.0

N. B.—To refer the tabular times to any year (limit about 10 years) subsequent to the epoch, *add* $0^m.35$ for every year. For years previous to epoch *subtract* $0^m.35$ for every year.

To refer the tabular times to any other latitude (between the limits 25° and 50°), *add* $0^m.14$ for every degree south of 40°; *subtract* $0^m.18$ for every degree north of 40°.

To refer the tabular times to any year in a quadriennium,

For first year after a leap year the table is perfect.
For second year after a leap year *add* . . . $1^m.0$
For third year after a leap year *add* . . . $2^m.0$
For a leap year and before March 1 *add* . . $3^m.0$
And for remainder of the year *subtract* . . $1^m.0$

For any other than the tabular day *subtract* from the tabular time of elongation $3^m.94$ for every day elapsed.

It will be noticed that there occur two eastern elongations on January 9, and two western elongations on July 9.

Azimuth (from the north) of Polaris, when at elongation, between the years 1882 and 1895, for different latitudes between +25° and +50°.

Lat.	1882.0	1883.0	1884.0	1885.0	1886.0	1887.0	1888.0	1889.0	1890.0	1891.0	1892.0	1893.0	1894.0	1895.0
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
+25	1 27.4	1 27.1	1 26.7	1 26.4	1 26.0	1 25.7	1 25.3	1 25.0	1 24.6	1 24.3	1 23.9	1 23.6	1 23.2	1 22.9
26	28.1	27.8	27.4	27.1	26.7	26.4	26.0	25.7	25.3	25.0	24.6	24.3	23.9	23.6
27	28.9	28.6	28.2	27.8	27.5	27.1	26.8	26.4	26.0	25.7	25.4	25.1	24.7	24.3
28	29.7	29.4	29.0	28.7	28.3	27.9	27.6	27.2	26.8	26.5	26.2	25.8	25.4	25.1
29	30.6	30.2	29.9	29.5	29.1	28.8	28.4	28.0	27.6	27.3	27.0	26.6	26.3	25.9
30	31.5	31.1	30.7	30.3	30.0	29.6	29.3	28.9	28.5	28.2	27.8	27.5	27.1	26.8
31	32.4	32.1	31.7	31.3	30.9	30.5	30.2	29.8	29.4	29.1	28.8	28.4	28.0	27.6
32	33.4	33.0	32.7	32.3	31.9	31.5	31.2	30.8	30.4	30.1	29.7	29.3	29.0	28.6
33	34.5	34.1	33.7	33.3	33.0	32.6	32.2	31.8	31.4	31.1	30.7	30.3	30.0	29.6
34	35.6	35.2	34.8	34.4	34.0	33.6	33.3	32.9	32.5	32.1	31.8	31.4	31.0	30.6
35	36.7	36.3	35.9	35.5	35.2	34.8	34.4	34.0	33.6	33.2	32.9	32.5	32.1	31.7
36	37.9	37.5	37.1	36.7	36.4	36.0	35.6	35.2	34.8	34.4	34.0	33.6	33.2	32.9
37	39.2	38.8	38.4	38.0	37.6	37.2	36.8	36.4	36.0	35.6	35.2	34.8	34.5	34.1
38	40.5	40.1	39.7	39.3	38.9	38.5	38.1	37.7	37.3	36.9	36.5	36.1	35.7	35.3
39	41.9	41.5	41.1	40.7	40.3	39.9	39.5	39.1	38.7	38.3	37.9	37.5	37.1	36.7
40	43.4	43.0	42.6	42.2	41.8	41.4	41.0	40.5	40.1	39.7	39.3	38.9	38.5	38.1
41	45.0	44.6	44.1	43.7	43.3	42.9	42.5	42.0	41.6	41.2	40.8	40.4	40.0	39.6
42	46.6	46.2	45.8	45.4	44.9	44.5	44.1	43.6	43.2	42.8	42.4	42.0	41.5	41.1
43	48.3	47.9	47.5	47.0	46.6	46.1	45.7	45.3	44.9	44.4	44.0	43.6	43.2	42.7
44	50.1	49.7	49.3	48.8	48.4	47.9	47.5	47.1	46.6	46.2	45.8	45.3	44.9	44.4
45	52.0	51.6	51.1	50.7	50.3	49.8	49.4	48.9	48.5	48.1	47.6	47.1	46.7	46.2
46	54.0	53.6	53.1	52.7	52.2	51.8	51.3	50.9	50.4	50.0	49.5	49.0	48.6	48.2
47	56.2	55.7	55.2	54.7	54.3	53.8	53.4	52.9	52.5	52.0	51.5	51.0	50.6	50.2
48	1 58.4	1 57.9	57.5	57.0	56.5	56.0	55.6	55.1	54.6	54.2	53.7	53.2	52.8	52.3
49	2 00.8	2 00.3	1 59.8	1 59.3	1 58.8	1 58.3	1 57.9	57.4	56.9	56.5	56.0	55.5	55.0	54.5
+50	2 03.3	2 02.8	2 02.3	2 01.8	2 01.3	2 00.8	2 00.3	1 59.8	1 59.3	1 58.8	1 58.4	1 57.9	1 57.4	1 56.9

To find the true Meridian with the Compass.

165. 1. Drive two posts firmly into the ground, in a line nearly east and west; the uppermost ends, after the posts are driven, being about three feet above the surface and at the same level, and the posts about four feet apart; then lay a plank, or piece of timber three or four inches in width, and smooth on the upper side, upon the posts, and let it be pinned or nailed, to hold it firmly.

2. Prepare a piece of board four or five inches square, and smooth on the under side. Let one of the compass-sights, or a piece of tin with a very small perforation, be fastened at right angles to the upper surface of the board, and place a brick or other weight upon the sight-board to keep it steady.

3. At about twelve feet from the stakes, and in the direction of the pole-star, let a plumb be suspended from the top of an inclined stake or pole. The top of the pole should be of such a height that the pole-star will appear about six inches below it; and the plumb should be swung in a vessel of water to prevent it from vibrating.

This being done, about twenty minutes before the time of elongation, place the board, to which the compass-sight is fastened, on the horizontal plank, and slide it east or west, until the aperture of the compass-sight, the plumb-line, and the star, are brought into the same range. Then if the star depart from the plumb-line, move the compass-sight, east or west, along the timber, as the case may be, until the star shall attain its greatest elongation, when it will continue behind the plumb-line for several minutes; and will then recede from it in the direction contrary to its motion before it became stationary. During this observation it will be necessary to have the plumb-line lighted; this may be done by an assistant holding a candle near it.

Now let a point be fixed by a second plumb-line placed at a distance of thirty or forty yards from the first, and in the same direction with it and the compass-sight. Mark the points determined by the two plumbs, for future reference, by driving pegs deeply into the ground and marking the exact point on each by a small nail. The line so determined, makes, with the true meridian, an angle equal to the azimuth of the pole-star; and, from this line, the variation of the needle is readily determined, even without tracing the true meridian on the ground.

Place the compass upon this line, turn the sights in the direction of it, and note the angle shown by the needle. Now, if the elongation at the time of observation was west, and the north end of the needle is on the west side of the line, the azimuth plus the angle shown by the needle, is the true variation. But should the north end of the needle be found on the east side of the line, the elongation being west, the difference between the azimuth and the angle would show the variation; and the reverse when the elongation is east.

It may be stated that for magnetic purposes a moderate degree of accuracy suffices in the determination of the true meridian, and a correct knowledge of it within 1′ will in general fully suffice. It is difficult, even in our middle latitudes, to determine the magnetic meridian within the limit of 1′ on account of the continuous fluctuations, hence any greater accuracy than this in the astronomic meridian would be useless.

166. A very near approximation to a true meridian, and consequently to the variation, may be had, by remembering that the pole-star very nearly reaches the true meridian, when it is in the same vertical plane with the star *Delta* (δ) in the constellation Cassiopeia.

Using the same apparatus as in Art. **165**, place the "sight-d" in line with the plumb-line and the pole-star, and move it to the *east* as the pole-star moves *west*, till Polaris and Delta both appear upon the plumb-line together; the line through the point of sight and the plumb-line will be, very nearly and with sufficient accuracy, the true meridian. This method is practicable only when the star Delta is *below* the pole-star during the night; when it passes the meridian *above* the pole, it is too near the zenith to be of service, in which case the star Zeta (ζ), the last star but one in the tail of the Great Bear, may be used instead.

Delta Cassiopeiæ is on the meridian below the pole-star at midnight about April 10, and is, therefore, the proper star to use at that date and for some two months before and after.

Six months later, the star Zeta in the tail of the Great Bear will supply its place, and is to be used in precisely the same manner.

Fig. 82 gives a representation, drawn to scale, of N. Pole, Polaris, and the Constellations Cassiopeia and Great Bear; and

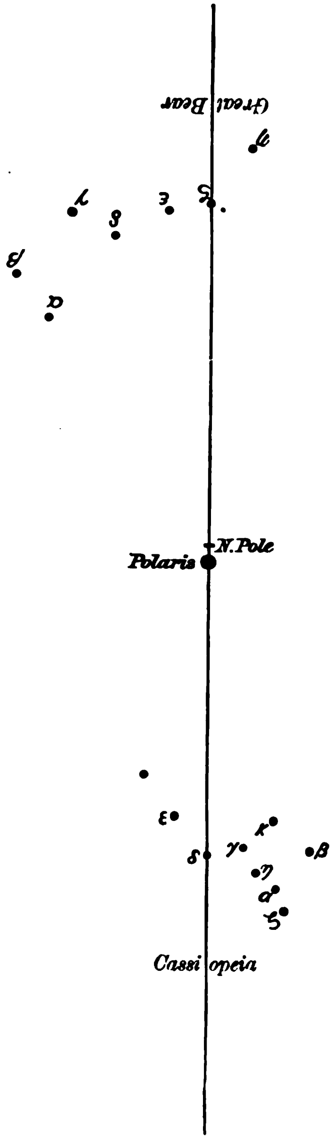


FIG. 82.

the line drawn through the star Delta (δ) of Cassiopeia and Zeta (ζ) of the Great Bear, represents those stars on the meridian with the pole-star.

The method given in this article for finding the true meridian cannot be used with advantage, on account of the haziness of the atmosphere near the horizon, at places below about 38° north latitude.

167. The variation of the needle should always be noted on every survey made with the compass, and then if the land be surveyed at a future time, the old lines can always be re-run.

In re-running the lines of an old survey, a *vernier* is used for setting off the variation of the needle.

168. A Vernier is a contrivance for measuring smaller divisions of a unit than those into which the line, to which it is applied, is divided. It is a graduated scale so arranged as to cover an exact number of equal spaces on the primary scale, or *limb*. It is divided into a number of equal parts greater by one than the number of equal spaces which it covers on the limb.

The vernier may be applied to any limb or scale of equal parts. The modes of its application are extremely various; the principle, however, is the same in all, and may be illustrated by a simple diagram (Fig. 83).

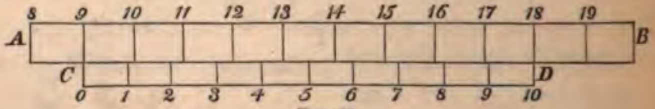


Fig. 83.

Let AB be any *limb* or scale of equal parts, one of which let us suppose equal to $\frac{1}{10}$ of an inch. Let CD be a *vernier*, equal in length, say to nine of these parts, and itself divided into ten equal spaces, each one of which is then equal to nine-tenths of $\frac{1}{10}$, or $\frac{9}{100}$ of an inch. The *difference* between a space on the limb and a space on the vernier, is therefore equal to one-tenth of

$\frac{1}{10}$, or $\frac{1}{100}$ of an inch. This is the least space that can be measured by means of the vernier, and is called the *least count;* hence,

The least count of a vernier is equal to one of the equal divisions of the limb divided by the number of spaces on the vernier.

169. The **true reading** of an instrument, for any position of the vernier, expresses the distance from the point where the graduation on the limb begins, marked 0, to the 0 point of the vernier. In the diagram, that distance is expressed by nine units of the limb, or 9.

If, now, the vernier be moved till the division 1 coincides with the division 10 of the limb, the 0 point will have advanced along the limb a distance equal to $\frac{1}{10}$ of one space, and, if we call each space b, the reading will become $9+\frac{1}{10}b$. If we again move the vernier till the division 2 coincides with the division 11 of the limb, the 0 point will have advanced an additional distance, equal to $\frac{1}{10}b$, and the reading becomes $9+\frac{2}{10}b$; when 3 coincides with division 12, the reading will become $9+\frac{3}{10}b$, and so on, till finally, when the point 10 coincides with 19 of the limb, the distance 9 will have been increased by $\frac{10}{10}b$, and will become 10, as it should, since, in that case, the 0 point will have been moved a whole space, and will coincide with the division 10 of the limb. Hence, the following rule for reading an instrument which has a vernier:

Read the scale, in the direction of the graduation, up to the line preceding the 0 of the vernier; this gives the number of whole units of the scale. Look along the vernier and find which of its lines coincides with a line of the scale; this line of the vernier gives the number of fractional parts of one unit of the scale to be added to the former reading.

170. In order to read a vernier correctly, especially if i one with which we are not familiar, it is necessary to esti *by the eye alone,* the fractional part of one unit to be ad then if the vernier reading is nearly the same as the *esti* we may record the reading with confidence; but if the esti and the vernier reading disagree largely, then the cause of disagreement will probably be a false reading of the vernier.

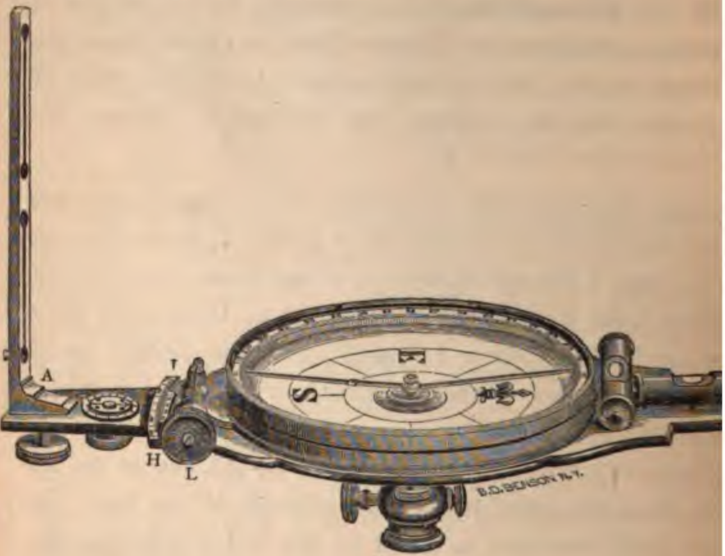


FIG. 84.

171. In a vernier compass, the vernier is attache shown in the figure. A small arc *HI* is described on th *AB,* having its centre at the centre of the compass-box. arc is divided to degrees, and sometimes to the parts of a de The vernier is permanently attached to the compass-box.

When the 0 point of this vernier coincides with the 0 of the graduated arc *HI,* the north and south line of the pass-box lies in the plane of the sights.

The compass-box is turned about its centre, without mo the plate AB, by means of the milled screw L: and is fastened to the plate AB, by a clamping nut underneath the main plate.

172. To set off the variation of the needle on a vernier compass, turn the *north* end of the compass plate by the tangent screw L of the vernier (see Fig. 84), over the number of degrees in the variation, to the *left* (the observer is supposed to be standing at the south end of the plate and looking towards the north end), if the variation is *westerly*, to the *right* if it is *easterly*.

173. To run out lines of old deeds, set the compass upon one end of an "original line," determined to be such by old "marks," or by testimony as to its having been undisputed for twenty years or more, and turn the vernier plate till the reading is the same as that given in the deed; then run the other lines by the bearings and distances as given in the deed.

174. To make allowance for change in "variation" in running out old lines, when only one "corner" can be identified, the surveyor must see to it that the date of the deed from which he is working is the same as the date of the *survey* from which the description of property in the deed is taken: very often descriptions are copied from former deeds, in which case the date of the *survey* must be discovered before running the lines.

175. If no "original" line of the property can be found, nor a corner and date of survey, then the surveyor must seek his data upon neighboring property and work back from there, through several deeds if necessary.

176. It is very desirable that the date of the survey from which a description is taken, and also the name of the surveyor, should be entered in every deed conveying lands.

The form of a "Survey Bill" may be somewhat as follows:

Description of Property in Town of ———, County of ———, State of ———, surveyed on the sixteenth day of August, in the year eighteen hundred and eighty-three, and bounded as follows:

Beginning at a point in the northwest corner of land owned by A. B. C., and marked by a cross cut into the top of a stone sunk three feet into the ground,—from which point the east chimney of the house of A. B. C. bore S 87½° E, distant 8.56 ch.—thence from the point of beginning N 18° E, 11.27 ch. to a stake;—thence N 56° E, 15.26 ch. to a corner where two stone walls meet;—thence S 87° E, 5.56 ch. to the shore line of the bay;—thence following the shore line to a point on the shore line bearing S 23° W, and distant in a straight line 13.47 ch.—from which point the middle of the eastern key-stone of the bridge across Beaver Dam Creek bears S 37½° E;—thence, following the middle of the road to a point in the middle of the road bearing S 87° W, distant in a straight line 5 ch.—thence, ...&c., &c.; the above described property containing, by calculation, — Acres, — Roods, and — Perches, more or less.

ERASMUS RUGGLES,

Variation of the needle —° —′ —″ W (or E). Surveyor.

BOOK IV.

TRANSIT SURVEYING.

SECTION I.

SURVEYOR'S TRANSIT.

177. The transit is an instrument used for measuring horizontal and (when furnished with a vertical circle) vertical angles. It is placed on a tripod, *TTT*, to which it is screwed fast by means of a horizontal brass plate, *DE*. Upon the upper surface of the plate *DE* rest four screws with milled heads, called leveling screws, which work through the second horizontal plate, *FG*, into cylindrical nuts, shown in the figure. The two plates *DE* and *FG* are called leveling plates. The lower leveling plate, *DE*, is made in two pieces—the upper piece, which is screwed fast to the top of the tripod, having a large opening in its centre, in which the smaller lower one is shifted from side to side, or turned completely around.

By this arrangement, termed a "shifting centre," the instrument is easily moved over the upper plate, and the plummet, which hangs from the centre, set precisely over a point without moving the tripod.

The upper side of the plate *DE* terminates in a curved surface, which encloses a ball that is nearly a hemisphere with the plane of its base horizontal. This ball or hemispherical nut is screwed fast to the smaller base of a solid conic spindle, that passes through the curved part of the plate *DE*. To this spindle is firmly attached the second horizontal plate, FG.

To this spindle, also, and above the plate *FG*, is fitted and fastened by spring-catch, a socket, called the main socket, to which is attached a third horizontal and circular plate, *BB*,

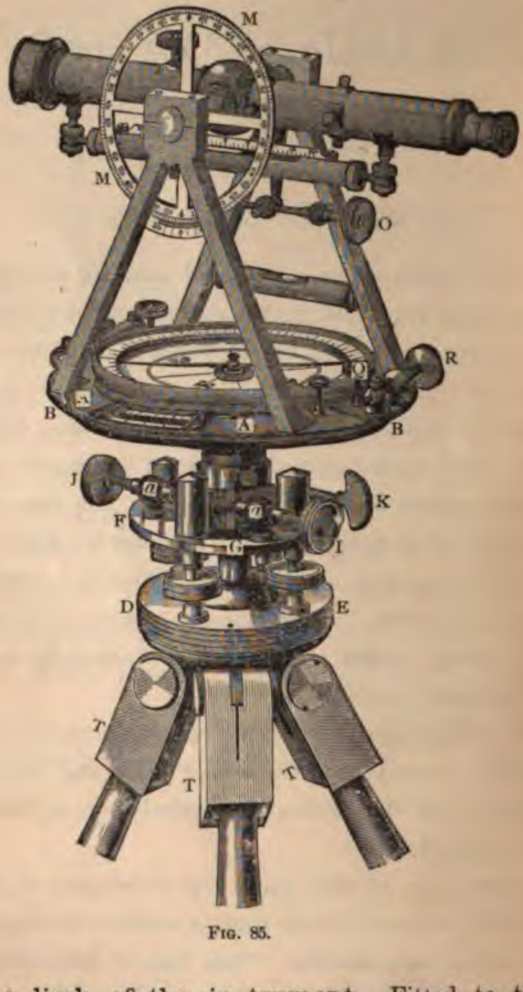


FIG. 85.

called **the limb of the instrument.** Fitted to the upper conical surface of the main socket is a second socket to which is united a thin circular plate, *AA*, called the **Vernier Plate,** which rests on the limb of the instrument and carries a compass-circle, standards, &c., as shown in Fig. 85.

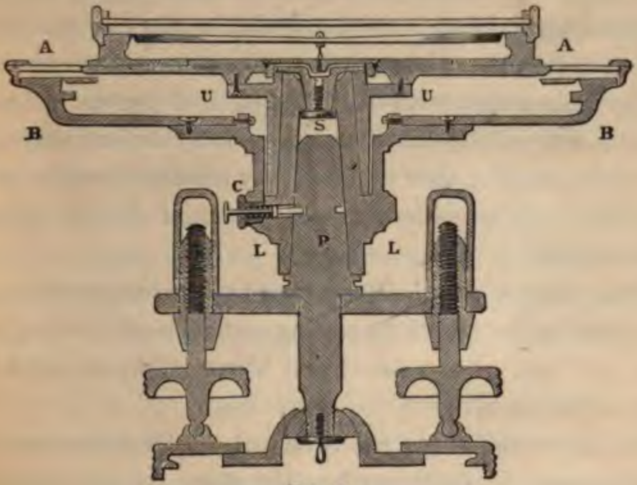


FIG. 86.

178. The sectional view, Fig. 86, shows the interior construction of the sockets of the transit, the manner in which it is detached from the spindle, and the means by which it can be taken apart if desired.

In the figure, the limb *BB* is attached to the main socket of *LL*, which is itself carefully fitted to the conical spindle *P*, and held in place by the spring catch *C*.

The upper plate, *AA*, carrying the compass-circle, standards, &c., is fastened to the flanges of the socket, *UU*, which is fitted to the upper conical surface of the main socket *L;* the weight of all the parts being supported on the small bearings of the end of the socket, as shown, so as to turn with the least possible friction.

A small conical centre, in which from below is inserted the strong screw, *S*, is brought down firmly upon the upper end of the main socket *LL*, and thus holds the two plates of the instrument securely together, while at the same time allowing them to move freely around each other in use.

A small disc above the conical centre contains the steel centre-pin upon which rests the needle, as shown; the disc is fastened to the upper plate by two small screws, as represented.

The main socket with all its parts is of the best bell-metal and is most carefully and thoroughly made, the long bearing of the sockets ensuring their firm and easy movement, while at the same time they are entirely out of the reach of dust, or other source of wear.

When desired the whole upper part of the instrument can be taken off from the spindle by pulling out the head of the spring-catch at *C*, and when replaced will be secured by the self-acting spring of the catch.

The figure also shows the covers of the leveling screws, the shifting centre of the lower leveling plate, and the screw and loop for the attachment of the plummet.

179. On the upper surface of the plate *FG*, Fig. 85, rests a clamp which goes round the main socket and which, being compressed by the clamp-screw *K*, is made fast to it. This clamp is thus connected with the plate *FG*. Two small cylinders, *aa*, are fastened to the plate *FG*; through these cylinders thumb screws, *II*, called slow-motion screws or tangent screws, pass and abut against opposite sides of a piece projecting from the clamp-ring, thus preventing the clamp from moving in either direction. When the clamp is compressed against the main socket by the clamp-screw *K*, the limb of the instrument is prevented from revolving. One of the tangent screws *I*, being then loosened as the other is tightened, will slowly and steadily move the clamp-ring itself and with it, of course, the limb.

The limb, *BB*, has a silvered circle near its outer edge, on which the graduation for horizontal angles is made. In the instrument described, the circle is divided into degrees and half degrees; the degrees are figured in two rows, viz: from 0 to 360, and from 0 to 90 each way.

The vernier plate, *AA*, has two openings, one of which is shown in the Figure 85, placed diametrically opposite each other, in which, attached to the plate *AA* and moving with it, are small silvered arcs called verniers, which serve to read the limb about which they revolve.

The verniers are double, having on each side of the zero mark thirty equal divisions corresponding precisely with twenty-nine half-degrees of the limb; they thus read to single minutes, and the number passed over is counted in the same direction in which the vernier is moved.

The use of two opposite verniers gives the means of testing the correctness of the graduations, the perfection with which they are centered and the dependence which can be placed upon the accuracy of the angles indicated.

Two spirit levels, at right angles to each other, are attached to the vernier plate by small adjusting screws, one being fixed to the standard which supports the telescope, so as not to obstruct the light which falls on the vernier opening beneath.

The vernier plate turns freely around with the socket to which it is attached. It is made fast to the limb by the clamp-screw *Q*, Fig. 85, after which the smaller motions are made by the tangent-screw *R*.

There is a compass on the vernier plate that is concentric with it, the uses of which have been explained under the head Compass. It also may be made to serve as a check upon the measurement of angles with the transit, as from the magnetic bearings of two courses may be found the angle between them, as explained in Art. **114**.

180. The standards which support the horizontal axes of the telescope with its attached level, rest on and are made fast to the vernier plate. The vertical circle *MM*, Fig. 85, called the **Vertical Limb**, is securely fastened to the axis of the telescope; it is plated with silver, graduated to half degrees, and with its vernier enables the surveyor to obtain vertical angles to single minutes. There is a clamp-and-tangent arrangement connected with the telescope; it consists of an arm at one end encircling the telescope axis, and at the other connected with the tangent-screw *O*, Fig. 85. The clamp is fastened at will to the axis by a clamp-screw, and then by turning the tangent-screw the telescope is raised or lowered as desired.

181. The *telescope* is from ten to eleven inches long, firmly secured to an axis having its bearings nicely fitted in the standards, and thus enabling the telescope to be moved in either direction, or turned completely around if desired.

The different parts of the telescope are shown in Fig. 87.

The object-glass is composed of two lenses, so as to show objects without color or distortion, is placed at the end of a slide having two bearings, one at the end of the outer tube, the other in the ring *CC*, suspended within the tube by four screws, only two of which are hown in the cut.

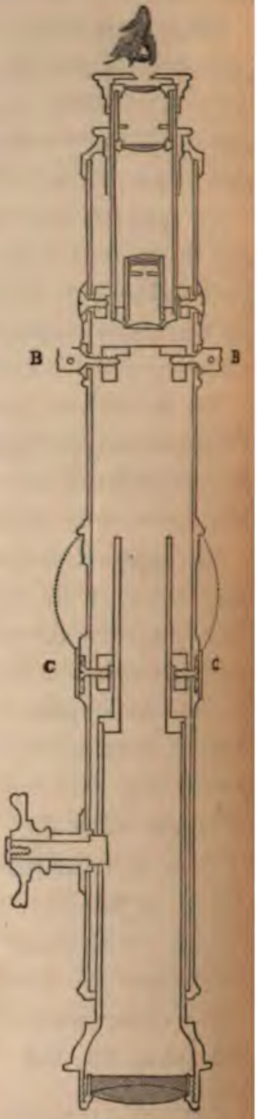


FIG. 87.

The object-glass is carried out or in by a pinion working in a rack attached to the slide, and thus adjusted to objects either near or remote as desired.

The eye-piece is made up of four plane convex lenses, which, beginning at the eye end, are called respectively the eye, the field, the amplifying, and the object lenses, the whole forming a compound microscope having its focus in the plane of the cross-wire ring *BB*.

The eye-piece is brought to its proper focus usually by twisting its milled end, the spiral movement within carrying the eye-tube out or in as desired; sometimes a pinion, like that which focuses the object-glass, is employed for the same purpose.

182. In order that the telescope may be directed to an object with precision, two spider's lines, or fine wires, are fixed at right angles to each other, and placed within the barrel of the telescope, and at the focus of the eye-glass.

The cross-wire diaphragm is a small ring of metal suspended in the tube of the telescope by four capstan-head screws, *ff*, *gg*, Fig. 88. The ring can thus be moved in either direction by working the screws with an adjusting-pin. Across the flat surface of the ring two fine fibres of spider's web, or, better, very fine platinum-wire, are extended at right angles to each other, their ends being cemented into fine lines cut in the metal of the ring.

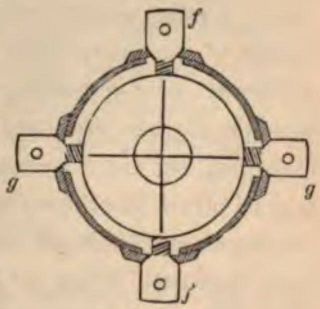


FIG. 88.

The intersection of the wires forms a very minute point which, when they are adjusted, determines the optical axis of the telescope, and enables the surveyor to fix it upon an object with the greatest precision.

The openings in the telescope tube are made considerably larger than the screws, so that, when these are loosened, the ring may be moved a short distance in the direction of the length of either wire for purposes of adjustment as hereafter described, and may also be slightly turned for the same purpose.

183. To measure horizontal angles correctly, the limb of the instrument must be made truly horizontal.

To level the instrument, extend the legs and place them so as to bring each bubble as nearly as possible to the middle of its tube. Turn the vernier plate till one of the levels is parallel to one pair of leveling screws, the other level will be parallel to the other pair of screws. If the bubble in either level is not at the middle, turn the leveling screws to which that level is parallel, in contrary directions, thus raising one side of the horizontal plate carrying the graduated circle and lowering the other till the bubble is brought to the middle of that tube; with the other pair of leveling screws, bring the bubble in the other level to the middle of the tube; when the bubbles in both levels are at the middle of their respective tubes, the plane of the levels, and, consequently, the graduated circle by which horizontal angles are measured, are truly horizontal. Two opposite leveling screws may be turned in contrary directions, by holding each screw with the thumb and forefinger, and turning so that both thumbs turn in, or both out. When the thumbs are turned outward, the left-hand side of the circle is raised; when both are turned inward, the right-hand side is raised. The bubble always runs to the end of the level which is too high.

If the leveling screws become jammed, so as to work hard, turn one of them only, forward or backward, till they are free again; sometimes they work hard, from setting the other pair tight while at a large angle of inclination with the lower plate, in which case the other pair must be loosened again.

ADJUSTMENTS OF THE TRANSIT.

Before using the instrument, it must be *adjusted;* that is, the parts must be brought to their proper relative positions. There are *four* principal *adjustments.*

FIRST ADJUSTMENT.—*To make the axes of the levels, on the limb, perpendicular to the axis of the instrument.*

184. Turn the horizontal limb until one of the levels is parallel to one pair of leveling screws ; the other will be parallel to the other pair. Bring the bubble in each tube to the middle with its parallel pair of leveling screws ; after which turn the horizontal limb half way round to reverse the levels, and if the bubbles remain in the middle of the tubes, the levels are properly adjusted. But if either bubble recedes from the centre, that level must be adjusted by raising the lower or depressing the higher end, one half by the leveling screws, and one half by the screws which fasten the level to the plate. Again reverse the levels, and if the bubble does not remain in the middle of the tube, correct the error as before, and repeat the operation till the bubble remains in the middle during an entire revolution of the plate.

Each level must be adjusted separately.

SECOND ADJUSTMENT.—*To fix the intersection of the cross-wires in the axis of the telescope, which is called the line of collimation.*

185. Having screwed the tripod to the instrument, extend the legs, and place them firmly. Level carefully, then loosen the clamp-screw *Q*, of the vernier plate, and direct the telescope to a small, well-defined, and distant object. Slide the eye-glass of the telescope till the cross-wires are distinctly seen; then with the thumb-screw, which forces out and draws in the object-glass, adjust this glass to its proper focus, when the object, as well as the cross-wires, will be distinctly seen; clamp the vernier plate and, by the tangent-screw R, bring the intersection of the cross-wires exactly upon a well-defined point of the object.

Now move the eye from side to side across the eye-glass; if there results any movement of the cross-wires away from the point sighted, it is evidence that the image of the point does not fall exactly upon the plane of the cross-wires, and the object-glass must be again focussed, till no such displacement can be detected. This displacement is called "parallax."

Having done this, sight some well-defined point, or the middle of a pin, distant two or three hundred feet, and having clamped the horizontal motions, revolve the telescope about its horizontal axis and sight a pin in the opposite direction from the first and at the same distance from the plumb; now loosen the lower clamp and, revolving the instrument about the vertical axis, sight the middle of the first pin again, and clamp; reverse the telescope upon the horizontal axis, and if it now cuts the second pin, as before, the adjustment is correct; but if the intersection of the wires falls on one side of the second pin, bring it back over *one quarter* of the error, by the capstan screws on each side of the telescope over the cross-wire ring. As the eye-piece inverts the position of the wires, the operation of loosening one of the screws and tightening the other on the opposite side, must be conducted as if to increase the error observed. To insure the accuracy of the adjustment, repeat the whole operation as above described, until the reversals cut the pins exactly.

186. The reason for the above directions will be apparent upon examination of Fig. 89.

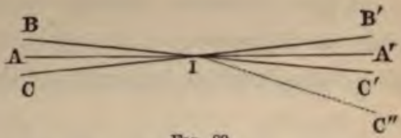


FIG. 89.

Let AA' represent the line of collimation prolonged both ways from the instrument at I, and suppose that the intersection falls at B, the cross-wires not being in adjustment; on reversing the telescope the intersection will fall at B', as far to the *left* of A' as B was to the *right* of A; if now we turn the instrument 180°, by the horizontal limb, the intersection will fall at C, to the left of A, CA being equal to BA, and on reversal the intersection will fall at C', $C'A'$ being equal to $A'B'$; if the cross-wires be moved over $C'A'$, the adjustment will be accomplished. But it is not well to risk introducing possible errors of graduation of the horizontal limb, or errors of reading, into the operation, and therefore instead of turning the instrument through 180°, the surveyor turns till he sights B the second time, thus passing over $180^\circ \pm CB$; this causes C' to fall at C'', $C'C''$ being equal to CB, and therefore $B'C''$ must be *four* times $C'A'$, or four times the error of adjustment.

187. The adjustment of the horizontal wire, which is only an approximation to perfect adjustment, is accomplished thus: Set the zero of the vertical limb at the zero of its vernier, and clamp; sight some sharply defined point upon a wall or staff, distant about 200 feet; unclamp and reverse the telescope upon its horizontal axis and set the zero of the vernier at 180° on the vertical limb; now unclamp the lower clamp and revolve the instrument upon its vertical axis till the chosen point is again in the field of view; if the point and the intersection of the cross-wires do not coincide, correct half the error by the screws, moving the cross-wire ring up or down, and the remaining half error by the leveling screws; repeat the operations till the error is wholly corrected.

If the instrument should not be furnished with a vertical limb, the adjustment of the horizontal hair can only be guessed at, by bringing it to the centre of the field of the telescope.

THIRD ADJUSTMENT.—*To make the axis of the attached level of the telescope parallel to the line of collimation.*

188. First level the instrument carefully, and with the clamp and tangent movement to the axis, make the telescope horizontal as near as may be with the eye; then having the line of collimation previously adjusted, drive a stake at a convenient distance, say from one to two hundred feet, and note the height cut by the horizontal cross-wire upon a staff set on the top of the stake. Fix another stake in the opposite direction and at the same distance from the instrument, and, without disturbing the telescope, turn the instrument upon its spindle, set the staff upon the stake, and drive in the ground until the same height is indicated as in the first observation. The top of the two stakes will then be in the same horizontal line, however much the telescope may be out of level.

Now remove the instrument from fifty to one hundred feet to one side of either of the stakes, and in line with both; again level the instrument, clamp the telescope as nearly horizontal as may be, and note the heights indicated upon the staff placed first upon the nearer and then upon the more distant stake.

If both readings do not agree, correct nearly the whole error of the more distant reading by the tangent screw, and continue correcting and reading until the two readings agree; now place a stake at a point in line with the two already fixed and about one hundred feet beyond the more remote, and mark upon it the point cut by the cross-wires, and mark also the corresponding point upon the more distant of the first two stakes; a line passing through these two marks will be a horizontal or level line with reference to the *first* position of the instrument, but not with reference to its present position.

Set the instrument again at its first position, and by the tangent-screw make the readings, above or below the marks, the same; the line of collimation will now be horizontal, and the bubble of the attached level must be brought, very carefully, to the middle of its run by the screws at the end of the level tube.

FOURTH ADJUSTMENT.—*To make the axis of the vertical limb perpendicular to the axis of the instrument.*

189. Bring the intersection of the cross-wires of the telescope upon a plumb-line, or any well-defined vertical object, and move the telescope with the thumb-screw O; if the intersection of the cross-wires continues on the vertical line, the axis is horizontal.

Or, the adjustment may be effected thus: Direct the intersection of the cross-wires to a well-defined point that is considerably elevated; then turn the vertical limb, until the cross-wires cut some other well-defined point, upon or near the ground; revolve the telescope on its axis, and turn the vernier plate 180°; then, if in elevating and depressing the telescope the line of collimation passes through the two points before noted, the axis is horizontal. If it be found, by either of the above methods, that the axis is not horizontal, it must be made so by adjusting the standards which support the telescope. One of these standards is made adjustable, and by raising the standard at the end towards which the deviation from the vertical occurs, or depressing the other, the adjustment is made.

SECTION II.

MEASUREMENT OF ANGLES.

190. To Measure with the Transit a Horizontal Angle subtended by two objects.—Place the axis of the instrument directly over the point at which the angle is to be measured. This is effected by means of a plumb, suspended from the centre of the plate which forms the upper end of the tripod.

Having made the limb truly level, place the 0 of the vernier at any exact degree (merely to avoid minutes and seconds in the first reading), and fasten the clamp screw Q of the vernier plate. Then, facing in the direction between the lines which subtend the angle to be measured, loosen the lower clamp and sight one of the objects very nearly, without wasting time in trying to secure perfect bisection by the cross-wires; tighten the lower clamp and make perfect bisection by the lower tangent screw.

This being done, loosen the clamp-screw Q of the vernier plate, and direct the telescope to the other object; the arc passed over by the 0 point of the vernier, is the measure of the angle sought; the difference of the two readings (if the 0° of the limb be not passed in turning to the second object), is the required angle; if the 0° be passed over, then add 360° to the smaller reading and subtract the greater reading from this sum. *Always be careful to take both readings from the same vernier.*

NOTE 1.—In measuring horizontal angles, it does not matter whether the telescope has to be elevated or depressed to sight either or both of the objects, since the telescope revolves on its axis in a vertical plane, and the angles measured are always the on [illegible] ons of the angle.

NOTE. 2.—When great accuracy is desired, a repetition, or several repetitions of the measure may be made, and a mean of the observations taken as the true measure. (See Arts. **254**, **255**.)

In the measurement of vertical angles, it is necessary to understand, first:

191. The method of determining the *index error* of the vertical limb. Having leveled the horizontal limb, direct the telescope to some distinctly marked object, as the top of a chimney, and read the instrument. Revolve the telescope on its axis and turn the vernier plate 180°, and having directed the telescope to the same object again, read the instrument. If the two readings are the same, the limb is adjusted; that is, the 0 of the limb coincides with the 0 of its vernier, when the axis of the telescope is parallel to the horizontal limb.

When the reading, found with the telescope in the first position, is greater than that obtained in the reversed position, the true elevation of the object, which is equal to a mean of the readings, may be obtained by *subtracting* half the difference from the first reading. If the first reading is less than the second, the half difference must be added to the first. Hence,

To find the index error, take the reading of the limb when the telescope is directed to a fixed object, and then with the telescope and vernier plate both reversed. Take half the difference of these readings, and affect it with a minus sign if the first is the greater, or a plus sign if the second is the greater; this is equal to the index error.

Let the operation be repeated several times, using different objects, and a mean of the errors will be more correct than the result of a single observation. Then, second:

192. Having determined the index error, let the axis of the clamp the vernier plate and direct the telescope to *C;* the reading will be the angle *RBC,* the azimuth of *BC* with *AB.*

Clamp the vernier plate and remove the instrument to *C;* reverse the telescope on its horizontal axis, loosen the lower clamp and sight *B;* the horizontal limb now has its zero point in the direction of *QP,* or its parallel *AR,* as it had at *B;* tighten the lower clamp and revolve the telescope on its axis; unclamp the vernier plate, direct the telescope to *D,* and the reading will be the angle *QCD,* which *CD* makes with *PQ,* or its parallel *AR,* and is the azimuth of *CD* with *AB.*

Clamp the vernier plate and remove the transit to *D;* reverse the telescope on its horizontal axis, loosen the lower clamp and sight *C;* the limb will then have its zero point in the direction *TS,* or its parallel *AR,* as it had at *C* and *B;* tighten the lower clamp and revolve the telescope on its axis; unclamp the vernier plate and direct the telescope to *E;* the reading will be the angle *TDE,* which *DE* makes with *TS,* or its parallel *RA,* and is the azimuth of *DE* with *AB.*

Proceed in like manner with any number of successive courses.

If the courses enclose a field, the reading at the last station, sighting to the first station occupied by the transit, should be 360°.

The course *AB,* with respect to which the azimuths are taken, is called the **Meridian of the Survey.**

195. The magnetic bearing of a line or course, is the angle which it makes with the magnetic meridian, and its true bearing is the angle which it makes with the true meridian.

In finding the area of a piece of ground, it is not necessary to have either the true or the magnetic bearing. It is sufficient to have the bearings of the several successive courses with respect to one of the courses taken as a meridian. These may be found from the azimuths as follows:

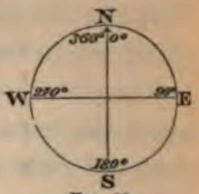


FIG. 92.

First suppose a north and south line, and an east and west line to be drawn, and the graduation to be made from 0° to 360°, as represented in Fig. 92; let the course taken as the meridian be represented by the line *NS;* then when the azimuth of the second course with the first, or meridian, is less than 90°, it is the bearing, and since the course lies between *N* and *E,* the bearing is *NE;* when the azimuth is 90°, the bearing is due east; when the azimuth is between 90° and 180°, the course lies between *S* and *E,* the bearing with the first course, or meridian, will be *SE,* and may be obtained by subtracting the azimuth from 180°; when the azimuth is 180°, the bearing is due south; when the azimuth is between 180° and 270°, the course lies between *S* and *W,* the bearing is, therefore, *SW,* and may be obtained by subtracting 180° from the azimuth; when the azimuth is 270°, the bearing is due west; when the azimuth is between 270° and 360°, the course lies between *N* and *W,* the bearing is *NW,* and may be obtained by subtracting the azimuth from 360°.

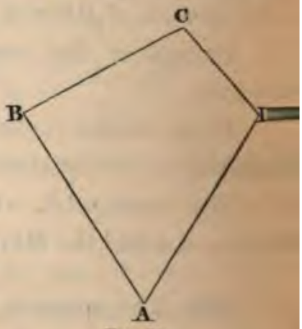


FIG. 93.

For example: Let *AB* (Fig. 93) be taken as the meridian, and let the azimuths of the several courses with *AB* be as in the table; then will the bearings of the several courses with th*B*, be as noted in the

TABLE.

Station.	Azimuth with *AB*.	Bearing with *AB*.
A	0°	North
B	93° 30′	S 86° 30′ E
C	175° 30′	S 4° 30′ E
D	257°	S 77° W

196. If it is desired to find the true or magnetic bearing of a course from its azimuth with a given course taken as a meridian, it may be obtained by finding the true or magnetic bearing of the course taken as meridian and subtracting it from, or adding it to, the azimuth of the given course, according as the bearing of the reference line is *NW* or *NE;* the result if less than 90° is the true, or magnetic bearing, and is *NE;* if more than 90° and less than 180°, subtract it from 180°, and the result will be the bearing, *SE;* &c.

For illustration, take the example in the last article, and let the magnetic bearing of the meridian course, or reference line, *AB*, be N 31½ W.

TABLE.

Station.	Azimuth with *AB*.	Bearing with *AB*.	Magnetic Bearing.
A	0°	North.	N 31½ W
B	93° 30′	S 86° 30′ E	N 62° E
C	175° 30′	S 4° 30′ E	S 36° E
D	257°	S 77° W	S 45° 30′ W

If *BC*, of which the magnetic bearing is N 62° E, had been taken as the reference line, its bearing would have been added to the azimuths to obtain the magnetic bearings of the successive courses, as follows:

Station.	Azimuth with *BC*.	Bearing with *BC*.	Magnetic Bearing.
A	86° 30′	93° 30′	N 31½ W
B	0°	North.	N 62° E
C	82°	98°	S 36° E
D	162° 30′	17° 30′	S 45½ W

NOTE.—For *SE* and *SW* in bearing of reference line, read *W* and *NE*, respectively, in applying the above rule.

To find the True Meridian with the Transit.

197. Before making the observations it will be necessary to devise some means by which the cross-wires may be lighted, that they may be distinctly visible.

To do this, take a board of about one foot square, paste white paper upon it and perforate it through the centre; the diameter of the hole being somewhat larger than the diameter of the telescope of the transit. Let this board be so fixed to a vertical staff as to slide up and down freely; and let a small piece of board, about three inches square, be nailed to the lower edge of it for the purpose of holding a candle.

About twenty-five minutes before the time of the greatest eastern or western elongation of the pole-star, as shown by the table of elongations (see Art. **164**), let the transit be placed at a convenient point and leveled. Let the board be placed about one foot in front of the transit, a lamp or candle placed on the shelf at its lower edge, and let the board be slipped up or down until the pole-star can be seen through the hole. The light reflected from the paper will show the cross-wires in the telescope of the transit.

Then let the vertical cross-wire be brought exactly upon the pole-star, and, if it is an eastern elongation that is to be observed and the star has not yet reached the most easterly point, it will move from the line toward the east, and the reverse when the elongation is west.

At the time the star attains its greatest elongation, it will appear to coincide with the vertical cross-wire for some time, and then leave it in the direction contrary to its former motion.

As the star moves toward the point of greatest elongation, the telescope must be continually directed to it by means of the tangent-screw of the vernier plate; and when the star has attained its greatest elongation, great care should be taken that the instrument be not afterward moved.

Next turn the telescope very carefully upon its horizontal axis and fix a peg in the ground, distant 150 or 200 feet; to do this, let the light of the lantern shine through a small hole in a board, across the centre of which hole a plumb-line hangs, and by sighting the line thus seen the peg may be fixed. Also mark the point directly under the transit plumb; the line passing through this point and the staff, makes an angle with the true meridian equal to the azimuth of the pole-star.

From the table of azimuths (see Art. **164**), take the azimuth corresponding to the year and nearest latitude. If the observed elongation was east, the true meridian lies on the west of the line which has been found, and makes with such line an angle equal to the azimuth. If the elongation was west, the true meridian lies on the east of the line found; and, in either case, laying off the azimuth angle with the transit, gives the true meridian.

198. Another method depends upon the fact that at the same angular distances east and west of the meridian the altitudes of any selected star are equal. Direct the transit to any bright star towards the south, and east of the meridian, and clamp the vertical limb; carefully read the horizontal limb; do not disturb the clamp and tangent of the vertical limb in any way, but loosen the clamp of the vernier plate, and after a sufficient interval of time, two or three hours perhaps, as it is not good practice to set the altitude when the star is too near the meridian, turn the plate upon its spindle towards the west; bring the star upon the cross-wire intersection as its altitude decreases, moving the *vernier plate only;* it will now have the same altitude as before; read the horizontal limb; take half the difference of the two readings, and set this half angle back towards the east; the line thus determined is the meridian.

APPLICATIONS TO HEIGHTS AND DISTANCES.

199. To determine the horizontal distance to a point which is inaccessible by reason of an intervening river.– Let C be the point (Fig. 94). Measure along the bank of the river a horizontal base-line AB, and select the stations A and B, in such a manner that each can be seen from the other, and the point C from both of them. Then measure the horizontal angles CAB and CBA, with the transit.

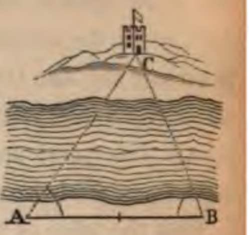


FIG. 94.

Let us suppose that we have measured

$$AB = 600 \text{ yards};$$

$$CAB = A = 57^\circ\ 35'',$$

and

$$CBA = B = 64^\circ\ 51'.$$

Then, $$C = 180^\circ - (A + B) = 57^\circ\ 34'.$$

To find the distance BC.

$$\sin C : \sin A :: AB : BC.$$

Applying logarithms, we have,

(a. c.)	log sin C (57° 34')	0.073649
	log sin A (57° 35')	9.926431
	log AB (600)	2.778151
	log BC 600.11	2.778231

To find the distance AC.

$$\sin C : \sin B :: AB : AC,$$

and applying logarithms, we have,

(a. c.)	log sin C (57° 34′)	0.073649
	log sin B (64° 51′)	9.956744
	log AB (600)	2.778151
	log AC 643.94	2.808544

To determine the altitude of an inaccessible object above a given horizontal plane.

FIRST METHOD.

200. Suppose D to be an inacessible object, and BC the horizonal plane from which the altitude is o be measured; then, if we suppose DC to be a vertical line, it will reprent the required distance.

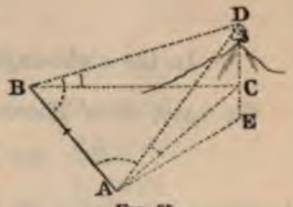


FIG. 95.

Measure any horizontal base-line, s BA; and at the extremities B and A, measure the horizontal ngles CBA and CAB. Measure, also, the angle of elevation DBC.

Then, in the triangle CBA, there will be known two angles nd the side AB; the side BC can therefore be found by alculation. Having found BC, we shall have, in the rightngled triangle DBC, the base BC and the angle at the base, o find the perpendicular DC, which measures the altitude of he point D above the horizontal plane BC.

Let us suppose that we have found, by measurement,

$$BA = 780 \text{ yards.}$$

The horizontal angle $CBA = B = 41° 24'$,
the horizontal angle $CAB = A = 96° 28'$,
and the angle of elevation $DBC = 10° 43'$.

To find, in the triangle BCA, the horizontal distance BC.

The angle $BCA = C = 180° - (A + B) = 42° 08'$.

Then, $\sin C : \sin A :: AB : BC$;

and applying logarithms, we have,

(a. c.)	log sin C (42° 08′)	0.173369
	log sin A (96° 28′)	9.997228
	log AB (780)	2.892095
	log BC 1155.29 yards . . .	3.062692

In the right-angled triangle DCB, to find DC.

We have, from Theorem IV,

$$R : \tan DBC :: BC : DC.$$

Applying logarithms, we have,

(a. c.)	log R (90°)	0.000000
	log tan DBC (10° 43′) . . .	9.277043
	log BC (1155.29) . . .	3.062692
	log DC 218.64	2.339735

NOTE 1.—It might, at first, appear, that the solution given requires that the points B and A should be in the same horizontal plane; but it is entirely independent of such a supposition.

For, the horizontal distance represented by BA is the same, whether the station A is on the same level with B, above it, or below it. The horizontal angles CAB and CBA are also the same, so long as the point C is in the vertical line DC. Therefore, if the horizontal line through A should cut the vertical line DC, at any point, as E, above or below C, AB would still be the horizontal distance between B and A, and AE would be the horizontal distance between A and C.

If at A, we measure the angle of elevation at the point D, shall know in the right-angled triangle DAE, the base AE d the angle at the base; from which the perpendicular DE n be determined.

Let us suppose that we had measured the angle of elevation AE, and found it equal to 20° 15′.

First: In the triangle BAC, to find AC, or its equal AE.

$$\sin C : \sin B :: AB : AC \text{ or } AE.$$

pplying logarithms, we have,

(a. c.)	log sin C (42° 08′)	0.173369
	log sin B (41° 24′)	9.820406
	log AB (780)	2.892095
	log AE* 768.9	2.885870

In the right-angled triangle DAE, to find DE.

We have, from Theorem IV,

$$R : \tan A :: AE : DE : \text{hence},$$

(a. c.)	log R (90°)	0.000000
	log tan A (20° 15″)	9.566932
	log AE (768.9)	2.885870
	log DE 283.66	2.452802

Now, since DC is less than DE, t follows that the station B is above he station A. That is,

$$DE - DC = 283.66 - 218.64 = 65.02 = EC,$$

hich expresses the vertical distance hat the station B is above the station A.

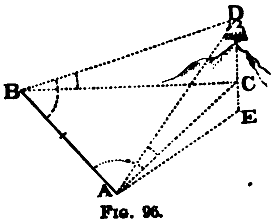


FIG. 96.

NOTE 2.—It should be remembered that the vertical distance, which is obtained by the calculation, is estimated from a horizontal line passing through the eye, at the time of observation. Hence, the height of the instrument is to be added, in order to obtain the true result.

SECOND METHOD.

201. When the nature of the ground will admit of it, measure a base-line AB, in the direction of the object D. Then measure, with the instrument, the angles of elevation at A and B.

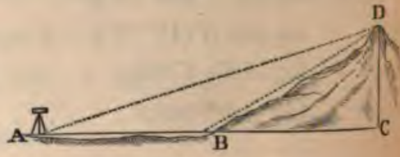


FIG. 97.

Then, since the outward angle DBC is equal to the sum of the angles A and ADB, it follows that the angle ADB is equal to the difference of the angles of elevation at A and B. Hence, we can find all the parts of the triangle ADB. Having found DB, and knowing the angle DBC, we can find the altitude DC.

This method supposes that the stations A and B are on the same horizontal plane; and therefore it can only be used when the line AB is nearly horizontal.

Let us suppose that we have measured the base-line and the two angles of elevation, and found,

$$AB = 975 \text{ yards}, \quad A = 15° \, 36', \text{ and } DBC = 27° \, 29';$$

required the altitude DC.

Ans. $DC = 587.61$ yards.

To determine the perpendicular distance of an object below a given horizontal plane.

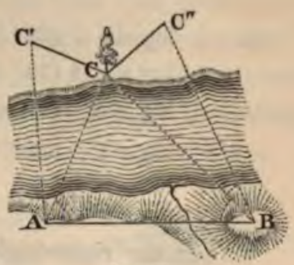


FIG. 98.

202. Suppose C to be directly over the given object, and A the point through which the horizontal plane is supposed to pass.

Measure a horizontal base-line AB, and at the stations A and B conceive the two horizontal lines AC, BC, to be drawn. The oblique lines from A and B, to the object, are the hypothenuses of two right-angled triangles, of which AC, BC, are the bases. The perpendiculars of these triangles are the distances from the horizontal lines AC, BC, to the object. If we turn the triangles about their bases AC, BC, until they become horizontal, the object, in the first case, will fall at C', and in the second at C''.

Measure the horizontal angles CAB, CBA, and also the angles of depression $C'AC$, $C''BC$.

Suppose that we have measured, and found $AB = 672$ yards; $BAC = 72° \ 29'$; $ABC = 39° \ 20'$; angle of depression $C'AC = 27° \ 49'$, and $C''BC = 19° \ 10'$.

First: In the triangle ABC, the horizontal angle $ACB = 180° - (A + B) = 180° - 111° \ 49' = 68° \ 11'$.

To find the horizontal distance AC.

$$\sin C : \sin B :: AB : AC; \text{ hence,}$$

(a. c.)	log sin C (68° 11′)	0.032275
	log sin B (39° 20′)	9.801973
	log AB (672)	2.827369
	log AC 458.79	2.661617

To find the horizontal distance BC.

$\sin C : \sin A :: AB : BC$; whence,

(a. c.)	$\log \sin C$	(68° 11′)	0.032275
	$\log \sin A$	(72° 29′)	9.979380
	$\log AB$	(672)	2.827369
	$\log BC$	690.28	2.839024

In the right-angled triangle CAC′, to find CC′.

We have, Theorem IV.,

$R : \tan A :: AC : CC'$; whence,

(a. c.)	$\log R$	(90°)	0.000000
	$\log \tan A$	(27° 49′)	9.722315
	$\log AC$	458.79	2.661617
	$\log CC'$	242.06	2.383932

In the triangle CBC″, to find CC″.

We have, Theorem IV.,

$R : \tan B :: BC : CC''$; whence,

(a. c.)	$\log R$	(90°)	0.000000
	$\log \tan B$	(19° 10′)	9.541061
	$\log BC$	(690.28)	2.839024
	$\log CC''$	239.93	2.380085

Hence, also, $CC' - CC'' = 242.06 - 239.93 = 2.13$ yard which is the height of station A above station B.

203.—PROBLEMS.

1. Wanting to know the distance between two inaccessible bjects, which lie in a direct level line from the bottom of a wer 120 feet in height, the angles of depression are measured om the top of the tower, and are found to be, of the nearer 7°, and of the more remote 25° 30′; required the distance etween the objects. *Ans.* 173.656 feet.

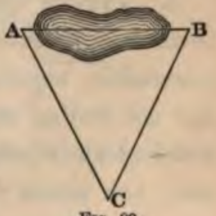


FIG. 99.

2. In order to find the distance between wo trees, *A* and *B*, which could not be irectly measured because of a pool which ccupied the intermediate space, the disnces of a third point *C* from each of them ere measured, and also the included angle *CB*; it was found that,

$$CB = 672 \text{ yards},$$
$$CA = 588 \text{ yards},$$
$$ACB = 55° 40′;$$

equired the distance *AB*. *Ans.* 592.967 yards.

3. Being on a horizontal plane, and wanting to ascertain the eight of a tower standing on the top of an inaccessible hill, here were measured, the angle of elevation of the top of the ill 40°, and of the top of the tower 51°; then measuring in a irect line 180 feet farther from the hill, the angle of elevation f the top of the tower was 33° 45′: required the height of the ower.

Ans. 83.998.

4. Wanting to know the horizontal distance between two naccessible objects *E* and *W*, the following measurements were nade;

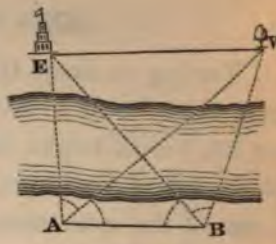


FIG. 100.

$$\text{viz.:}\begin{cases} AB = 536 \text{ yards} \\ BAW = 40° \, 16' \\ WAE = 57° \, 40' \\ ABE = 42° \, 22' \\ EBW = 71° \, 07'; \end{cases}$$

required the distance EW.

Ans. 939.617 yards.

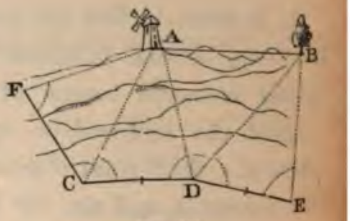


FIG. 101.

5. Wanting to know the horizontal distance between two inaccessible objects A and B, and not finding any station from which both of them could be seen, two points C and D were chosen at a distance from each other equal to 200 yards; from the former of these points A could be seen, and from the latter B, and at each of the points C and D a staff was set up. From C a distance CF was measured, not in the direction DC, equal to 200 yards, and from D a distance DE equal to 200 yards, and the following angles taken,

$$\text{viz.:}\begin{cases} AFC = 83° \, 00', & BDE = 54° \, 30', \\ ACD = 53° \, 30', & BDC = 156° \, 25', \\ ACF = 54° \, 31', & BED = 88° \, 30'. \end{cases}$$

Ans. $AB = 345.459$ yards.

6. From a station P there can be seen three objects, A, B, and C, whose distances from each other are known : viz.,

$$AB = 800, \quad AC = 600, \quad \text{and} \quad BC = 400 \text{ yards}.$$

Now, there are measured the horizontal angles,

$$APC = 33° \, 45', \quad \text{and} \quad BPC = 22° \, 30';$$

it [illegible] to find the three distances, PA, PC, and PB.

GEOMETRICALLY.

the three given sides construct ıgle *ABC*. Then, at *A* lay off ɜ $BAD = 22° 30'$, and at *B* the $BD = 33°\ 45'$, and note *D*, the which the two lines intersect.

ıgh the points *A*, *D*, and *B*, de- e circumference of a circle, and *C* and *D* draw the line *CDP*; t *P* in which it intersects the rence, will be the position of the station.

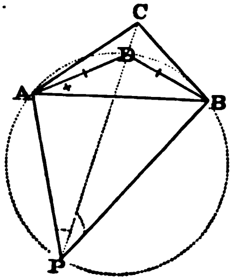


FIG. 102.

bserving the equal angles in the figure, the trigono- solution is not difficult. We find,

$$Ans. \begin{cases} PA = \ \ 710.198 \text{ yards.} \\ PC = 1042.524 \quad `` \\ PB = \ \ 934.289 \quad `` \end{cases}$$

.—This problem is much used in maritime surveying, purpose of locating buoys and sounding-boats. The etrical solution is somewhat tedious, but the geomet- ıtion is very easy, as shown above.

SECTION III.

RANGING OUT LINES, ETC.

204. To range out a line with the transit, place the instrument, carefully adjusted, over the first station; direct the telescope to a distant and well-defined point in the desired line, and clamp both the vernier plate and the horizontal limb. The line of sight of the telescope is then in the vertical plane of the given line, so that points on the surface bisected by the intersection of the cross-wires will be in the required line; let an assistant, directed into the line by the observer at the transit, fix ranging-rods, or stakes conspicuously marked, as far as the power of the telescope extends. Remove the transit to the third or fourth stake from the last set, and place it precisely over that position by plumb-bob, and adjust it for observation; the telescope is ranged in the line by sighting backwards and forwards to the stakes already set. The line is then continued as before.

If great accuracy be required, each operation must be repeated with telescope reversed, as only in this way can error in adjustment of cross-wires be eliminated. If the sighting with reversed telescope does not agree with the former sighting, take a point midway between the two points sighted, as a point in the required line.

205. A line may be traced in forests or plantings, in which there are no general surface obstructions, by the aid of auxiliary parallel lines.

In the illustration, Fig. 103, *aa*, *bb*, *cc*, are the parallel lines, and *aa*, *cc*, the auxiliary lines. *AB* is a line in which *b* is a given point. The distances *ab*, *bc*, in this line should be measured, and also the angle which *bb* makes with *AB*. The line *bb* and the auxiliary lines should be traced on this angle, until the trace of one of the parallel lines be obstructed by a tree,

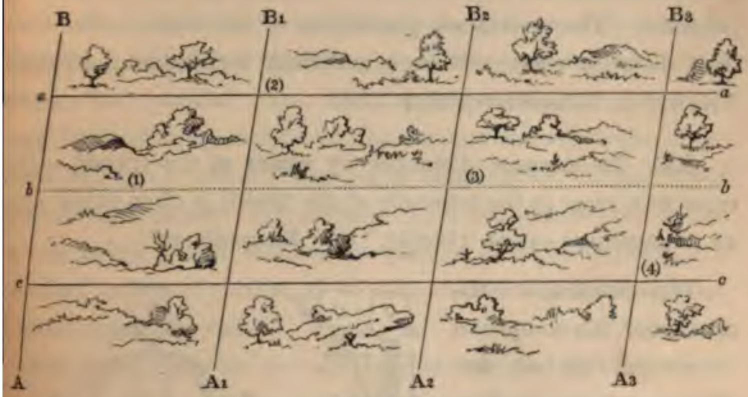


FIG. 103.

such as *bb* at (1). Immediately on passing the obstruction on one of the auxiliary lines, a line should be traced on the measured angle or its supplement, as may be required, and traced to intersect the other auxiliary line. The angle made by these lines should be measured at the point of intersection to verify the trace of the intersecting lines. From these angular points in the auxiliary lines, distances to the point (1), equal to *ab* and *cb*, respectively, should be measured in the transverse line, and found to meet, but not overlie, one another. Then will the point of meeting in the transverse line be a forward point in the line *bb*. At a suitable distance forward from which the point (1) may be observed, a like determination of another point in *bb* should be made. The trace of the line *bb* should be taken upon these points and continued in connection with the auxiliary lines until the trace of one of the lines be obstructed, such as the line *aa* at (2). The trace of the obstructed line should be taken up by measurements in the transverse line

B_1A_1, and in a forward parallel line, and the traces continued as described above. In like manner the obstructions at (3), (4), &c., may be passed, and the trace of the line continued for considerable distances with sufficient accuracy for most practical purposes. The continued parallelism of the lines at the measured distance apart will be a sufficient verification (Smith's Treatise on Land Surveying.)

206. To measure distances by means of the transit.—The cross-wire ring in the telescope of the transit is often fitted with an arrangement called "Stadia," or "Micrometer."

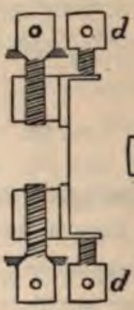


FIG. 104.

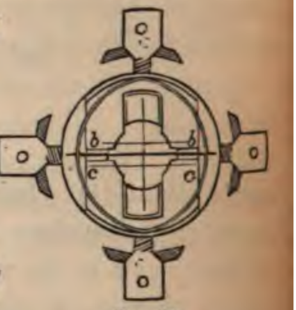


FIG. 105.

The Stadia, or Micrometer, is a compound cross-wire ring or diaphragm, shown in Figures 104 and 105, having three horizontal wires, of which the middle one is cemented to the ring as usual, while the others, *bb* and *cc*, are fastened to small slides, held apart by a slender brass spring hoop, and actuated by independent screws, *dd*, by which the distance between the two movable wires can be adjusted to include a given space upon a rod, held perpendicular to the optical axis in front of the object-glass, at a distance from it equal to its principal focal distance.

When the wires are thus adjusted to include a certain space, as two feet for instance, upon a rod placed at a distance of 100 feet from the specified point on the optical axis, it is found that they will cover one foot at half that distance, or four feet at a distance of 200 feet; thus the distance is proportional to the space intercepted upon the rod. By adding to the distance thus obtained, the principal focal distance of the object-glass, plus the distance of the object-glass from the middle of the horizontal axis, the distance of the rod from the station can be ascertained without the use of a chain.

The focal distance of the object-glass can be readily obtained by sighting some very distant object, being careful to correct instrumental parallax (Art. **185**), and then measuring the distance from the object-glass to the capstan screws of the cross-wire ring, which call a; now sight some object, distant about 100 feet, and measure the distance from the object-glass to the horizontal axis, which call b; the sum of these, $a+b$, will be a constant, sufficiently exact, to be added to all distances obtained by readings on the rod.

The spaces upon the rod used should be equal to that which the instrument intercepts at 100 feet from the point in front of the object-glass, and should be numbered from the bottom up; each space should be subdivided into hundredths. The rod should have two movable targets, like those used upon leveling rods, and should also be furnished with an attached plumb, or level, to insure its vertical position. A distinct mark should be made upon it at the ordinary height of the horizontal axis of the instrument.

In using the micrometer, sight the middle horizontal hair to the "height of instrument" mark, and then direct the targets to be moved successively till they coincide with the micrometer wires, the rod being kept vertical. If the telescope has been level during this operation, the distance given by the rod plus the instrument constant, can be recorded; but if the line of sight has been elevated or depressed, then from the distance given by the rod, including the instrument constant, must be subtracted the product of this distance and the square of the sine of the angle of deviation from the horizontal.

If distances greater than 600 feet are to be measured, the unit of the rod must be less than $\frac{1}{50}$ of the standard distance, to avoid the use of a rod too long for practical management.

If the distances are to be recorded in chains and links, set the stadia staff at 66 feet in order to obtain its unit, and then graduate it to this unit, and subdivide to hundredths.

The stadia staff should be spiked, that it may be thrust into the ground to secure steadiness.

The telescope should be a good one, giving a very sharp, clear definition of objects, and the micrometer wires should be very fine indeed in order to secure close readings.

The degree of accuracy that may be attained is shown by the following table, deduced from that given in "Cours de Topographie, par A. Lehagre, 1881," to which the student is referred for a very full description of the method:

Focal length of object-glass in inches	6	8	10	12	14
Distance in feet which may be safely measured	600	800	1000	1200	1400
Relative error in horizontal distance	$\frac{1}{600}$	$\frac{1}{800}$	$\frac{1}{1000}$	$\frac{1}{1200}$	$\frac{1}{1400}$

With a telescope of ten inches focal length or over, and within the above limits, the stadia measurements are as reliable as chain measurements on fairly level ground, and are much more accurate than chain measures on bad, broken country. As the use of the micrometer requires care and consumes time, it is not recommended for short distances, except on bad ground, swamps, inaccessible distances, &c.

207. In connection with the chain or tape, the transit is used to obtain horizontal distances on sloping ground. The chaining is made on the surface of the sloping ground, and not by elevati[illegible]in as described in Art. **71**; and the angle of the slope is taken with the transit, by marking on a rod the vertical distance from the horizontal axis of the telescope to the ground, and sighting to this mark on the rod held vertical at the end of the line measured; the horizontal distance is equal to the measured distance multiplied by the cosine of the angle of the slope.

208. To survey a line, such as a road, boundary of an estate, &c., measure the angle of deviation which each line makes with the preceding line prolonged, or measure the azimuths which each line makes with the first line taken as a meridian (Art. **194**), and measure, also, the length of each line and offsets to prominent objects. Care must be taken to centre the instrument exactly over each angular point, as any error in centreing will cause an error in the apparent direction of the object sighted, which will be the greater the nearer the object is to the instrument.

209. To survey the streets of a town or city, place the transit at the intersection of two or more of the principal streets, through which the longest lines of sight can be had; find the angle which each of the streets diverging from this point makes with the principal street, and find, also, the angle of slope of each of the streets at this point; measure, with the chain or stadia-rod, or both as checks one upon the other, the lengths of the lines of sight, and take offsets to the corners of all streets, to public buildings and prominent objects; remove the transit to the next street and take the angles, angle of slope, measurements, and offsets as before, and so continue till the survey is complete.

SECTION IV.

FARM SURVEYING BY TRANSIT.

210. The figure and area of any piece of ground may be found by beginning at any one of the angular points and going entirely around the boundary, measuring the length of the sides by chain or stadia-rod, and the angle which each side makes with the preceding side prolonged, called **Angle of Deviation,** or the azimuths of the several sides with a given first side as meridian. Let the farm to be surveyed be the one given in Article **123**. Let the side *AB* be taken as the meridian of the survey. Measure with the transit the azimuths of the several successive sides with *AB*, as directed in Art. **194**, and enter them in the notes at the left of the station mark. In the following illustration both the azimuth and the angle of deviation have been entered, though the surveyor would use but one, together with the bearings, which should always be entered as a check:

Azimuths.	Angles of Deviation.		Bearings.
			N 30° 35′ E
99° 30′	123° 30′ |⁄ D	△	(N 87° 5′ E)
		22.89	S 87° 5′ W
336° 00′	100° 55′ ⟍| C	△	(S 7° 50′ W)
		1.40	N 8° E
76° 55′	76° 55′ |⁄ B	△	(S 68° 55′ E)
		31.95	
	A	△	N 68° 55′ W

From the azimuths determine the bearings of the several sides with *AB*, as directed in Art. **195**, and let them be as noted on the following page; complete the table and determine the area as in a compass survey:

Stations.	Azimuths with *AB*.	Bearing with *AB*.	Distances	Latitude.		Departure.		Balanced		D. M. D.		Area.	
				+	—	+ E	— W	Lat.	Dep.	+	—	+	—
A	0°	North	31.95	31.95		0		+31.96	0	0		0	
B	76° 55′	N 76° 55′ E	1.40	.32		1.36		+ .32	+1.36	1.36		.4352	
C	336°	N 24° W	22.89	20.91			9.31	+20.92	—9.32		6.60		138.0720
D	99° 30′	S 80° 30′ E	8.39		1.38	8.28		—1.38	+8.28		7.64	10.5032	
E	111°	S 69° E	23.91		8.56	22.32		—8.55	+22.31	22.95			196.2225
F	156°	S 24° E	14.51		13.26	5.90		—13.25	+5.90	51.16			677.8700
G	184° 25′	S 4° 25′ W	7.55		7.53		.58	—7.53	—.58	56 48			425.2944
H	177° 55′	S 2° 05′ E	12.21		12.20	.44		—12.20	+ .44	56 34			687.3480
I	221° 55′	S 41° 55′ W	17.39		12.94		11.62	—12.93	—11.63	45.15			583.7895
K	278° 55′	N 81° 05′ W	16.97	2.63			16.76	+2.64	—16.76	16.76		44.2364	
				55.81	55.87	38 30	38.27					55.1748	2708.5964
					55.81	38.27							55.1748

Error in Northing . . . .06 | .03 Error in Westing.

Offsets between C and D to be added, 15.945 chains.

To be subtracted, 15.188 chains.

Leaving to be added, .757 chains.

2) 2653.4216
1326.7108
.757
1327.4678 sq. chains.

132.74678 acres.
4
2.98712 roods.
40
39.4848 perches.

Ans. 132 *A.* 2 *R.* 39.48 *P.*

211. If the surveyor does not record compass-bearings, as advised to do in last article, the notes may be kept in precisely the same manner as the field notes of the compass survey, as shown in Article **123**—substituting *azimuths* for the *bearings* of the several courses, and *angles* instead of *bearings* for the prominent objects sighted to.

212. If the angles of deviation had been measured instead of the azimuths, the method of finding the area would have been substantially the same. The azimuths would have been determined from the angles measured, and the rest of the computation would have remained the same. The azimuth of any course with a course taken as meridian may be found from the angles of deviation, thus: The azimuth of the course taken as meridian is zero; the azimuth of the second course is equal to its angle of deviation; the azimuth of any succeeding course is equal to the azimuth of the preceding course increased by the angle of deviation of the course itself, as a simple diagram will show. If the *interior* angles had been measured, the angles of deviation would have been obtained by subtracting each interior angle from 180° and the method would have been:

Stations.	Interior Angles.	Angles of Deviation.	Azimuth with *AB*.
A	98° 55′	81° 05′	0
B	103° 05′	76° 55′	76° 55′
C	280° 55′	—100° 55′	(—24°) 336°
D	56° 30′	123° 30′	99° 30′
E	168° 30′	11° 30′	111°
F	135°	45°	156°
G	151° 35′	28° 25′	184° 25′
H	186° 30′	—6° 30′	177° 55′
I	136°	44°	221° 55′
K	123°	57°	278° 55′

The other columns as before.

213. When an angle of deviation lies within the boundary of the survey, as at *C*, (see page 87), it must be called negative; when it lies without the boundary, it is an exterior angle of the polygon and is positive. The azimuth obtained by the rule may be negative (as it is in the case of the course *CD*); but as the azimuth must be positive, 360° must be added to the negative result obtained to get the true azimuth.

The algebraic sum of the angles of deviation should be equal to or differ but little from 360°, which fact serves to check the correctness of the angles recorded.

214. Where all the corners of a field may be seen from one of them, the area may be determined as follows:

Place the transit over the point *A*, Fig. 106, from which the other corners may be seen, and measure the angles *BAC*, *CAD*, and *DAE*. Measure the lengths of the diagonals *AC* and *AD*, and of the sides *AB* and *AE*; then the areas of the triangles *ABC*, *CAD*, and *DAE*, may be separately found from the principle that the area of a triangle is equal to half the product of two sides and the sine of their included angle; the sum of the areas of the triangles is equal to the area of the field.

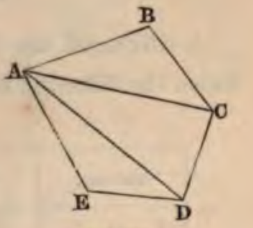


FIG. 106.

215. If a description of the property is also required, the bearing of some one of the lines must be taken, and from this and the recorded angles and distances, the "Bearings and Courses" may be computed.

216. Where all the corners of the field may be seen from a point within, as *A*, Fig. 107. Place the transit over the point *A*; measure the angles *BAC*, *CAD*, &c., at *A*, and the length of the lines *AB*, *AC*, &c., from *A* to the several corners of the field; find the areas of the triangles *BAC*, *CAD*, &c., as in the last article, and add them together. If the boundary is irregular, as represented in the figure, measure offsets, calculate the contents of these smaller portions separately, and add or subtract them as may be necessary, to find the true area of the tract.

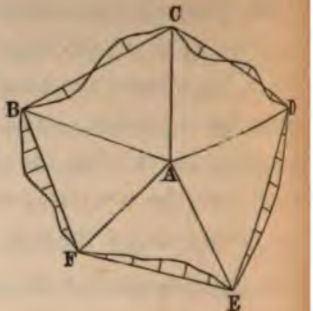


FIG. 107.

217.—EXAMPLES.

1. Required the contents and plot of a piece of land, of which the following are the field notes:

Stations.	Azimuths with *AB*.	Distances.
A	0°	15.8 ch.
B	34°	17.4
C	70° 30′	32.56
D	154° 30′	14.88
E	189°	24.96
F	230°	14.
G	279°	32.8
A	360°	

2. Required the contents and plot of a piece of land, of whic the following are the field notes:

Stations.	Interior Angles.	Distances.
A	92° 30′	31.80 ch.
B	94° 30′	2.08
C	155° 15′	2.21
D	179° 30′	35.35
E	94° 15′	21.10
F	104°	31.30

Required the area of a piece of land, of which the follow-
easurements were made:

$AB = 20$ chains
$AC = 22.57$
$AD = 28.64$
$AE = 40.80$
$AF = 30.95$

$BAC = 37°$
$CAD = 46° 45'$
$DAE = 42° 15'$
$EAF = 26°$

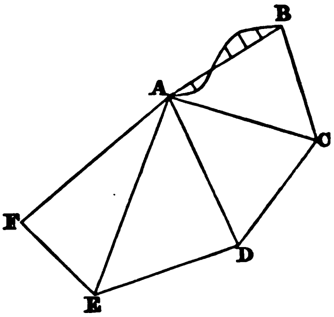


Fig. 108.

fsets from the line AB were taken as follows:

At 3.00 ch.	R	offset	2.50 ch.
" 6.50 "		"	0.00 "
" 9.50 "	L	"	1.60 "
" 13.00 "	L	"	2.00 "
" 16.00 "	L	"	1.40 "
" 20.00 "		"	0.00 "

BOOK V.

LAYING OUT AND DIVIDING LAND.

SECTION I.

OF DIVIDING LAND.

218. The surveyor is often required to lay off a given quantity of land, in such a way that its bounding lines shall form a particular figure, viz., a square, a rectangle, a triangle, &c. He is also often called upon to divide given pieces of land into parts containing given areas, or, into areas bearing certain relations to each other.

The manner of making such divisions must always depend on a skilful and judicious application of the principles of geometry and trigonometry to the particular case.

For example, if it were required to lay out an acre of ground, in a square form, it would be necessary to find, by calculation, the side of such a square, and then trace, on the ground, a figure bounded by four equal sides at right angles to each other.

219. To lay out a given quantity of land in a square form.

RULE.—*Reduce the given area to square chains or square rods; then extract the square root, and the result will be the side of the required square. This square being described on the ground, will be the figure required.*

220. **To lay out a given quantity of land in a rectangular form, when one of the sides of the rectangle is given.**

RULE.—*Divide the given area, reduced to square chains or square rods, by the given side of the required rectangle, and the quotient will be the other side. Then, trace the rectangle on the ground.*

221. **To run a line from the vertex of a triangular field which shall divide it into two parts, having to each other the ratio of m to n.**

Let ABC be any triangular field.

Divide the side BC into two parts, such that (Geom., Bk. IV, Prob. I)

$$BD : DC :: m : n;$$

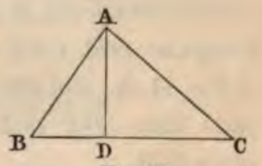


FIG. 109.

and draw the line AD;

then will $$ABD : DAC :: m : n.$$

For, the two triangles ABD, ADC, having the same altitude, are to each other as their bases (Geom., Bk. IV, P. 6, C.); hence, the triangle is divided into parts having the ratio of m to n.

222. **To run a line parallel to one side of a triangular field, that shall form with the parts of the two other sides a triangle equal to the $\frac{m}{n}$ part of the field.**

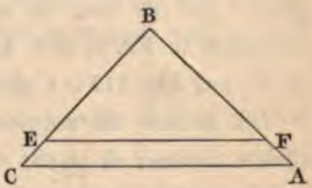


FIG. 110.

Let CBA represent a triangular field, and CA the side parallel to which the dividing line is to be drawn.

On the side BC, take BE equal

to $BC\sqrt{\frac{m}{n}}$, and on the side BA, take BF equal to $BA\sqrt{\frac{m}{n}}$; the line EF is the line required; for, since it divides the sides BC and BA proportionally, it is parallel to the side CA (Geom., Bk. IV, P. XVI); and from the similar triangles, we have (Geom., Bk. IV, P. XXV),

$$BEF : BCA :: \overline{BE}^2 : \overline{BC}^2,$$

or
$$BEF : BCA :: m : n;$$

hence,
$$BEF = \frac{m}{n}BCA.$$

EXAMPLE.—Let it be required to divide the triangular field CAB, in which $AC = 9$ ch., $AB = 11$ ch., and $CB = 7$ ch., into two such parts that ADE shall be one-fourth of the whole field.

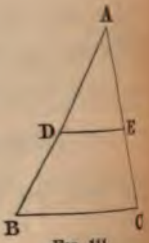


FIG. 111.

In this case, we have,

$$m = 1, \quad n = 4, \quad \text{and} \quad \sqrt{\frac{m}{n}} = \sqrt{\frac{1}{4}} = \frac{1}{2};$$

hence, $AE = 4$ ch. 50 l., and $AD = 5$ ch. 50 l.

223. **To run a line from a given point in the boundary of a piece of land, so as to cut off, on either side of the line, a given portion of the field.**

Make a complete survey of the field, by the rules already given. Let us take, as an example, the field whose area is computed in Ex. 1, Art. **140**. That field contains 105 *A*. 2 *R*. 33 *P*., and Fig. 112 is a plot of it.

Let it now be required to run a line from station *A* in such a manner as to cut off, on the left, any part of the field; say, 26 *A*. 2 *R*. 31 *P*.

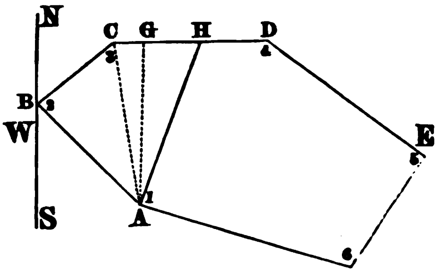


FIG. 112.

It is seen, by examining the field, that the division line will probably terminate on the course *CD*. Therefore, draw a line from *A* to *C*, which we will call the *first closing line.*

The bearings and lengths of the courses *AB*, *BC*, are always known, and in the present example are found in the table Art. **140**, Ex. 1; hence, the bearing and distance from *C* to *A* can be calculated by Art. **142**; they are, in this example,

Bearing, S 9° 28′ E; Course, 23.22 ch.

Having calculated the bearing and length of the closing line, find, by the general method, the area which it cuts off; that area, in the present case, is 14 *A*. 0 *R*. 26 *P*.

It is now evident that the division line must fall on the right of the closing line *AC*, and must cut off an area *ACH*, equal to the difference between that already cut off, and the given area; that is, an area equal to 12 *A*. 2 *R*. 5 *P*.

Since the bearing of the next course *CD*, and the bearing of the closing line *AC* are both known, the angle *ACD* which they form with each other, can be calculated, and is in this example, 79° 32′. Hence, knowing the hypothenuse *AC*, and the angle *ACG* at the base, the length *AG*, the perpendicular let fall on the course *CD* can be found, and is 22.82 chains.

The base of a triangle is equal to its area divided by half the altitude. Therefore, if the area 12 *A*. 2 *R*. 5 *P*. be reduced to square chains, and divided by 11.41 chains, is half the perpendicular AG, the quotient, which is 10.95 chains, will be the base CH. Hence, if we lay off from C, on CD, a distance CH, equal to 10.95 chains, and then run the line AH, it will cut off, from the land, the required area, viz.,

26 *A.* 2 *R.* 31 *P.*

NOTE 1.—If the part cut off by the first closing line should exceed the given area, the division line will fall on the left of AC.

NOTE 2.—If the difference between the given area and the first area cut off, divided by half the perpendicular AG, gives a quotient larger that the course CD; then, draw a line from A to D, and consider it as the first closing line, and let fall a perpendicular on DE.

NOTE 3.—When the point from which the division line is to be drawn falls between the extremities of a course, divide the course into two parts, at this point. Then consider one of the parts as an entire course, and the other as forming a new course, having the same bearing. The manner of making the calculation will then be the same as before.

224. To cut off from a field, a given area, by a line running in a given direction.

In this case, as in the previous one, a complete and correct survey is first necessary. Then, when the whole area is known, the position of the line may be approximately determined by the inspection of a correct map of the whole.

We will take, for illustration, Example 4, Art. **140**, of which Fig. 113 is the plot.

Let it be required to cut off from this area, 50 acres, by a line whose bearing shall be S 60° E, or N 60° W.

We will make a trial of a line starting at 25 chains from station 6, on the 6th course. We will call this station *A*, and the trial line *AB*.

In order to determine if the area cut off is equal to the required area, we must first determine the length of *AB* and of *B* 5. These cannot be determined by the method of supplying lost notes.

We must first calculate the length of a line, starting at the proposed point, and running to the station nearest to the other extremity of the closing line. In this example, from *A* to 5. This is easily found to be 36.406 chains, and its bearing N 81° 13′ E.

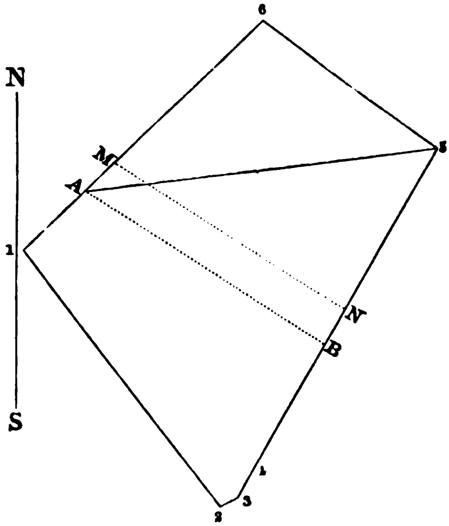


FIG. 113.

Now, in the triangle $AB5$ we have one side and the angles, to find the remaining parts. AB is found to be 28.88 chains and $B5$ to be 22.81 chains. We have now the complete field-notes of the area cut off.

A	S 60° E	28.88 ch.
B	N 28¾° E	22.81
5	N 57° W	21.10
6	S 47° W	25.00

The area is found to be 58.5029 acres.

It now remains to move this line northerly, so that the area contained between its present position and the new one shall be equal to 8.5029 acres.

Suppose the lines $A6$ and $B5$ be prolonged till they meet at some point, as V, Fig. 114.

Calculate AV and BV, also the area ABV. AV is found to be 92.19 chains and BV 88.18 chains. The area of the triangle ABV, is 127.29 acres. Let MN represent the line sought. Then, we have two similar triangles, with all the sides of the one, and the areas of each, known; for, VMN must contain 8.5029 acres less than AVB. Then, AM and BN are easily determined.

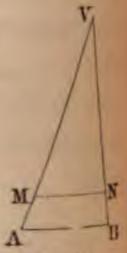


Fig. 114.

The complete notes of the area to be cut off, are

M	S 60° E	27.89
N	N 28¾° E	19.82
5	N 57° W	21.10
6	S 47° W	21.87

NOTE.—Fields are so variously shaped that it is difficult to give rules that will apply to all cases. It is by practice alone that facility is obtained in that branch of surveying relating to the division of estates. We have given only a few examples that may serve as general guides in the application of the principles of Plane Geometry to such cases as may arise.

SECTION II.

PUBLIC LANDS OF THE UNITED STATES.

225. Soon after the organization of the government, several of the States ceded to the United States large tracts of wild land, and these, together with the lands since acquired by treaty and purchase, constitute the public lands, or public domain. These lands were at first parceled out without reference to any general plan, in consequence of which the titles often conflicted with each other, and in many cases, several grants covered the same area. Through many years of labor and experiment, the present admirable system has been wrought out.

226. This system is briefly that the territory to be surveyed shall be divided by true north and south, and east and west lines, into tracts, each of six miles square and containing as near as may be 23,040 acres, called **Townships**; each township into thirty-six tracts, each of one mile square and containing as near as may be 640 acres, called **Sections**; and each section into halves, quarters, and smaller portions, as may be deemed expedient.

227. In the survey, all primary lines north and south are run on meridians of longitude, and all primary lines east and west are laid out on perpendiculars to the meridians.

It is of the first importance, then, that meridians of longitude should be accurately determined, and that lines perpendicular to them should be determined with equal precision.

The ordinary Surveyor's Compass is, for several reasons, not sufficiently accurate for the work of running out the standard and township lines, and such lines must be run by Burt's Solar Compass, "or other instrument of equal utility."

228. The Solar Compass for determining a true meridian was invented by William A. Burt, of Michigan, and patented by him in 1836. It has been improved, by him and others, from time to time since, and in its present state is represented and described in Appendix A.

229. In commencing the division of the public lands in unsurveyed territory, an initial point is selected, with reference to its convenience in making the survey, perpetuated by a substantial monument suitably marked, and its true position in latitude and longitude determined.

230. From the initial point the principal base line is run out due east and west with the solar compass, and permanently marked at each 40 chains, or half mile, with a quarter-section corner, and at each 80 chains, or mile, with a section corner.

231. The principal meridian is then run out due north and south from the initial point, and also marked with monuments at intervals, like the base line.

232. As meridians of longitude converge toward the poles, the distance between two such meridians decreases as the surveyor goes north. To counteract the error that would otherwise result from the convergency of meridians, and also to arrest error arising from inaccuracies in measurements on meridian lines, *standard parallels*, or correction lines, are run east and west from the principal meridian and at stated intervals. On the *north* of the principal base-line, about latitude 35° north, these standard parallels are, in general, run at distances of every *four* townships, or twenty-four miles, and *south* of the principal base, at distances of every *five* townships, or thirty miles. Each of these standards is run out and marked in the same way as the principal base, and forms the base for laying out the townships north to the next standard parallel. The standards are numbered according to their position with respect to the principal base-line, as 1st Standard Parallel South, 2d Standard Parallel South, 1st Standard Parallel North, &c.

233. The principal meridian, the base-line, and the standard parallels having been first run, measured, and marked, and the corner boundaries thereon established, the exterior lines of townships are then run, measured, and marked.

The townships, consisting of a series of townships lying along a parallel, are numbered north or south of the principal base; the first series north of the base being Township 1 North, the second series north being Township 2 North, &c.; and the first series south being Township 1 South, &c.; these are designated T. 1 N., T. 2 N., T. 1 S., &c.

The ranges, consisting of tiers of townships, are numbered from the principal meridian both ways; the first tier west of the meridian being Range 1 West, the first tier east being Range 1 East, &c.; designated R. 1 W., R. 1 E., &c.

234. The accompanying map, from the U. S. General Land Office, representing a considerable portion of the State of Arkansas, will serve for illustration.

The principal meridian in this survey is called the 5th

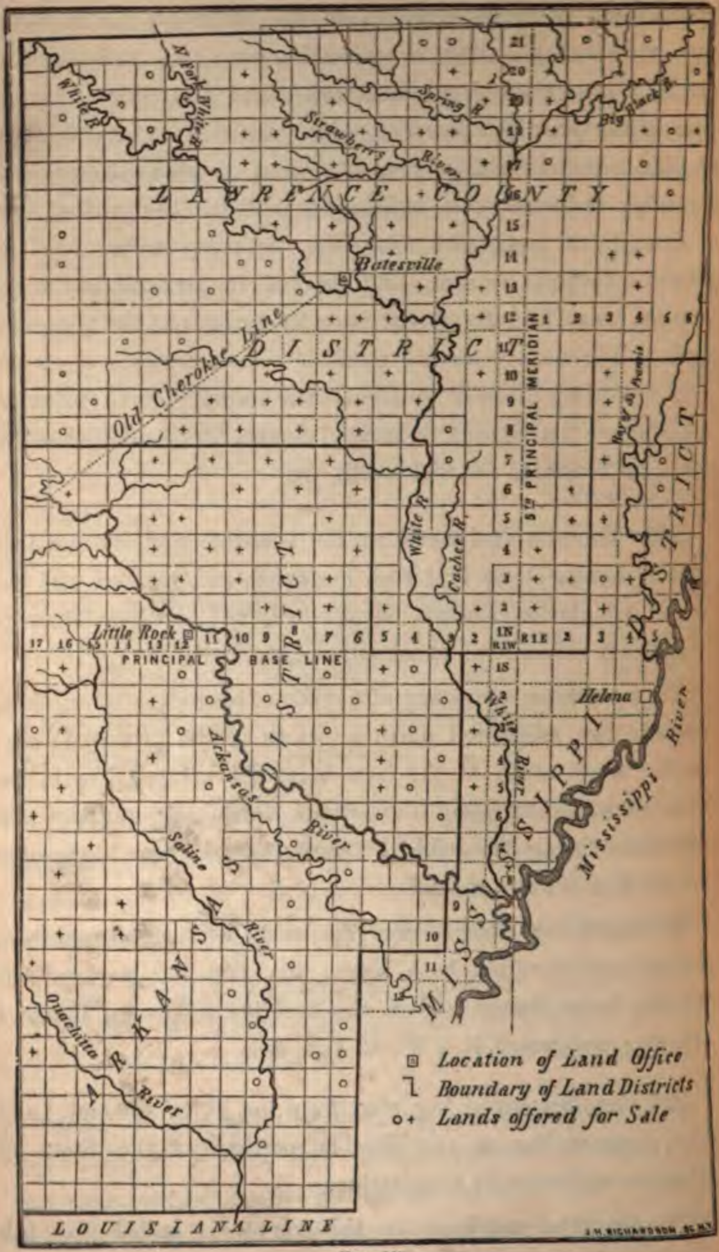

LAWRENCE COUNTY
DISTRICT
Batesville
Old Cherokee Line
White R.
N. Fork White R.
Strawberry River
Spring R.
Big Black R.
5th PRINCIPAL MERIDIAN
Little Rock
PRINCIPAL BASE LINE
1N
R1W
R1E
White R.
Cache R.
Bayou de View
DISTRICT
ARKANSAS DISTRICT
Arkansas River
Saline River
Ouachita River
MISSISSIPPI
Helena
Mississippi River
White River
LOUISIANA LINE
Location of Land Office
Boundary of Land Districts
Lands offered for Sale
J.H. RICHARDSON SC. N.Y.

FIG. 115.

meridian, and passes through the point of junction of the White river with the Mississippi. The principal base-line, running east and west, intersects this meridian a little to the east of White river; and from the meridian and base-line, reckoned from this point of intersection, all the ranges of townships are laid off.

For example, 1 North, will apply to all the townships lying in the first row north of the base-line; 1 South, will apply to all the townships in the first row south of the base line. Range 1 East, will apply to all the townships lying in the first row, east of the 5th meridian; and Range 1 West, will apply to all lying in the first row to the west of it. The small figures designate the rows of townships, reckoned north and south from the base-line, and the ranges reckoned east and west from the 5th meridian. Thus, Township 1 North, Range 4 West, has its exact place designated, and may be immediately located.

235. The diagram here given (Fig. 116), from the "Instructions to the Surveyors-General of Public Lands of the United States," represents the required method of running out township lines.

In the diagram, the upright figures (made thus, 1, 2, 3) commencing near the Principal Meridian and Base Line with No. 1, indicate the perambulations of the Surveyor in running the Townships and Correction lines.

The Correction or Standard lines north of the base are every four townships, and south of the base every five townships.

The excess or deficiency of measurement on northern and southern boundaries is thrown on the westernmost half-mile.

The measurements between meridian lines will, of course, always vary according to the latitude of the survey, besides being liable to be rendered inexact where the country is very hilly or broken. The convergency of the range lines as shown by the measurements on this diagram, is according to calculation, as it exists between the parallels of 46° and 47° North Latitude.

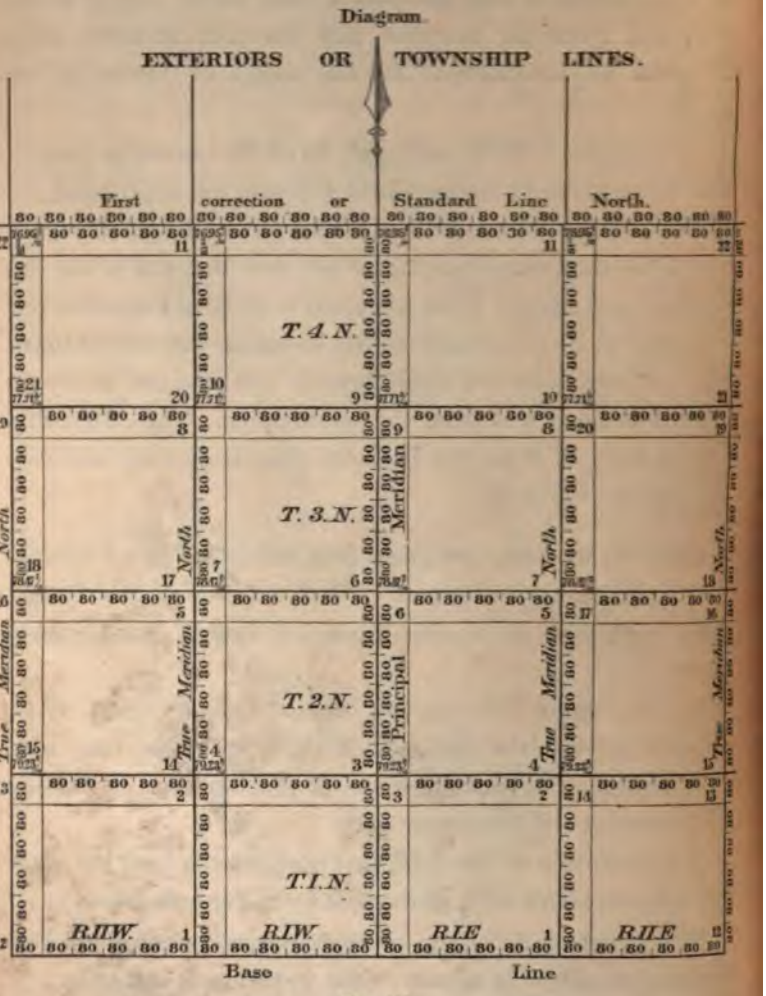


FIG. 116.

236. The "Instructions to the Surveyors-General" for running, measuring, and marking the exterior lines of townships, are as follows:

Townships situated North of the Base Line and West of the Principal Meridian.

Commence at No. 1 (see figures on the diagram, Fig. 116), being the southwest corner of T. 1 N.—R. 1 W., as established on the base line; thence north on a true meridian line, four hundred and eighty chains (6 miles), establishing the section and quarter-section corners thereon, as per instructions, to No. 2, whereat establish the corners of Tps. 1 and 2 N.—Rs. 1 and 2 W.; thence east, on a random or trial line, setting *temporary* section and quarter-section stakes to No. 3, where measure and note the distance at which the line intersects the eastern boundary, north or south of the *true* or established corner. Run and measure westward, on the true line (taking care to note all the land and water crossings, &c., as per instructions), to No. 4, which is identical with No. 2, establishing the section and quarter-section *permanent corners* on said line. Thence proceed in a similar manner from No. 4 to No. 5, No. 5 to No. 6, No. 6 to No. 7, and so on to No. 10, the southwest corner of T. 4 N.—R. 1 W. Thence north, still on a true meridian line, establishing the mile and half mile corners, until reaching the **Standard Parallel** or correction line; throwing the *excess* over, or *deficiency* under *four hundred and eighty chains*, on the *last* half mile, according to law, and at the intersection establishing the "**Closing Corner,**" the distance of which *from* the standard corner must be measured and noted as required by the instructions. But should it ever so happen that some impassable barrier will have prevented or delayed the extension of the standard parallel along and above the field of the present survey, then the deputy will plant, in place, the corner for the township, subject to correction thereafter, should such parallel be extended.

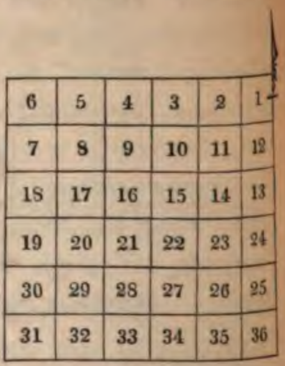
North of the Base Line and East of the Principal Meridian.

Commence at No. 1, being the *southeast* corner of T. 1 N.—R. 1 E., and proceed as with townships situated "north and west," except that the *random* or trial lines will be run and measured *west*, and the *true* lines east, throwing the excess over or deficiency under four hundred and eighty chains on the *west end* of the line, as required by law; wherefore the surveyor will commence his measurement with the length of the deficient or excessive half-section boundary on the west of the township, and thus the remaining measurements will all be *even* miles and half miles.

237. In running *random* township exteriors, if such random lines fall short or over-run in length, or intersect the eastern or western boundary, as the case may be, of the township, at more than *three chains and fifty links* north or south of the true corner, the lines must be *retraced*, even if found necessary to re-measure the meridional boundaries of the township.

238. The exterior lines of townships having been established and duly marked, each township is divided into 36 squares, called **Sections**, by meridians one mile apart, and by east and west lines at the same distance from each other. The sections of a township are numbered from 1 to 36, beginning at the north-east angle and proceeding as shown in the annexed diagram :

To describe a section accurately, we say, for example, section number 5, in township number 4 north, in range 3 west of a known meridian.



6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

FIG. 117.

239. The sections are divided

into half-sections, quarter-sections, and even into eighths of sections. The following table shows the contents of a township and its subdivisions:

1 township = 36 sections = 23040 acres.
1 section = 640 acres.
$\frac{1}{2}$ section = 320 acres.
$\frac{1}{4}$ section = 160 acres.
$\frac{1}{8}$ section = 80 acres.

240. As any excess or deficiency of measurement is, by law, to be thrown on the extreme tier of sections and half-sections contiguous to the north and west boundaries of townships, such sections and half-sections are sold as containing only the quantity expressed in the returns and plots, respectively, and all others as containing the complete legal quantity.

The government surveyors are rarely required to subdivide a section into quarters, as that work properly belongs to the county surveyors.

NOTE.—The student is referred, for more detailed information on Government Surveys, to: Instructions to the Surveyors-General of Public Lands of the United States, prescribed by the Commissioner of the General Land Office; Clevenger's Government Surveying; Burt's Solar Compass.

BOOK VI.

TRIGONOMETRICAL SURVEYING.

SECTION I.

MAKING THE SURVEY.

241. Trigonometrical Surveying, or **Triangulation**, is the method of determining the position of points on the surface of the earth by the application of the principles of Trigonometry—each successive point being determined by the intersection of two lines which make known angles with a given line. It may be used in small or extensive surveys; it does not necessarily take into account the curvature of the earth, though always used in the great surveys, such as the U. S. Coast Survey, in which that is considered.

242.* In the construction of a true map of any large territory, three things are necessary. The first of these is to ascertain the exact relation to each other, as to distance and direction, of the leading features of the country; selecting such high points as may be seen from the greatest distance, and connecting the whole by a chain of triangles of the largest dimensions practicable, and of the forms most convenient for accuracy of computation.

The series must rest upon a base of which the geographical position has been established with mathematical accuracy. The points which form the several angles of the chain will thus be fixed with equal exactness as points of the general surface of the earth. With the sides of this principal chain of triangles as bases, a net of smaller triangles is then to be constructed occupying the interior of the larger, and resting their angles upon the most conspicuous objects observable from the principal stations. And within these still a third series is to be formed, connecting as many of the less important points within those of the second order as the objects of the survey may seem to require. Every angle of every series of these triangles marks a geographical point determined with the same degree of precision as that of the original base from which the triangulation began. The base on which the New York State Survey rests is a side 23 miles long of one of the large triangles of the United States Coast Survey, a magnificent work which twenty years since pushed its operations to the head of tide-water upon the Hudson River. The bases of the United States Coast Survey itself are lines of some miles in length, determined in position by astronomical observation, and actually measured on the ground from end to end, by means of apparatus of extreme delicacy, constructed especially for the purpose.

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* Report of N. Y. State Survey, 1878.

243. The specimen of triangulation, Fig. 118, is from a survey, made by Professor Rees of Columbia College, of Otsego Lake, N. Y., for the N. Y. State Survey, and will serve to illustrate the method of making and plotting such a survey.

244. Before commencing a trigonometrical survey, an examination of the entire territory should be made for the purpose of selecting a base line and proper points for stations; this examination should be more or less elaborate according to the nature and extent of the survey.

The proper distribution and combination of the triangles, so as to adapt them to the survey in hand, require great judgment and care, and the selection of proper trigonometrical points is a

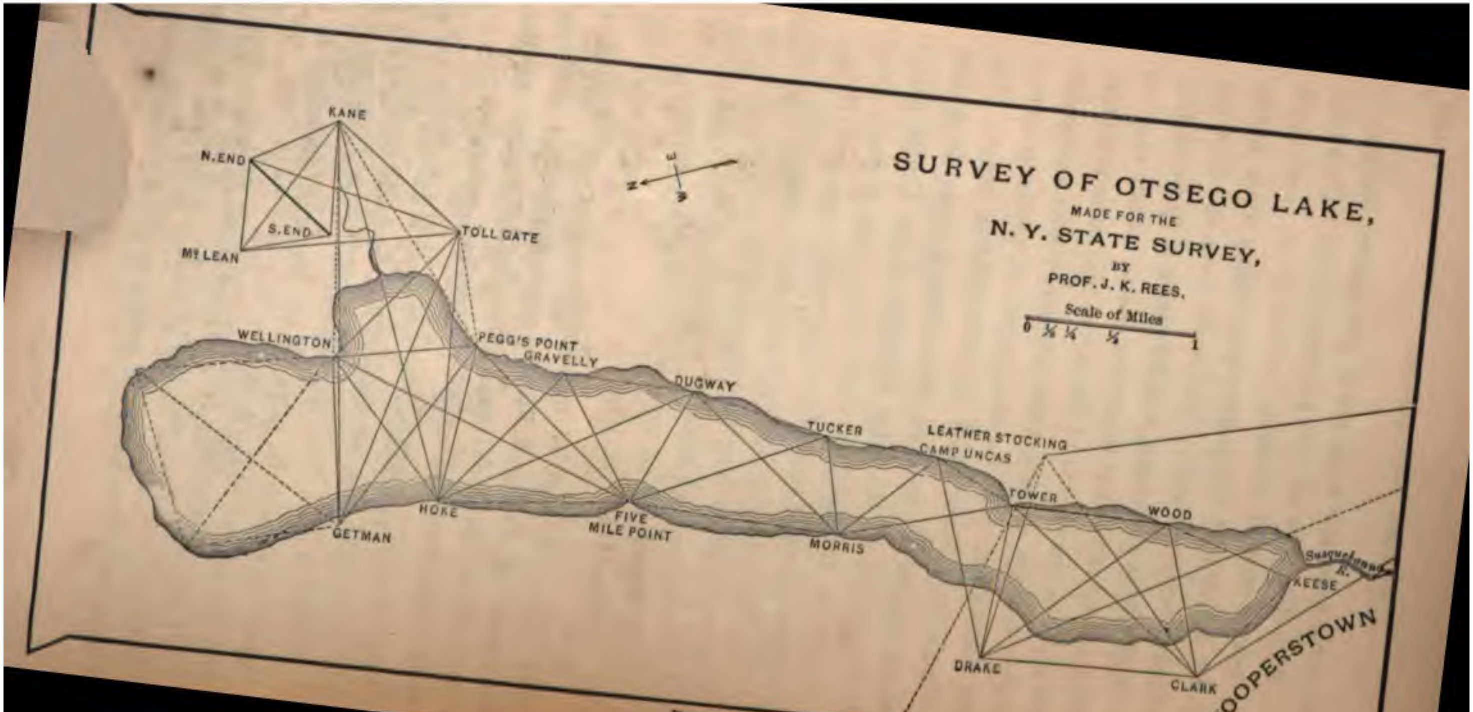

SURVEY OF OTSEGO LAKE,
MADE FOR THE
N. Y. STATE SURVEY,
BY
PROF. J. K. REES.
Scale of Miles
0 ⅛ ¼ ½ 1
N
E
S
W
KANE
N. END
S. END
McLEAN
TOLL GATE
WELLINGTON
PEGG'S POINT
GRAVELLY
DUGWAY
TUCKER
LEATHER STOCKING
CAMP UNCAS
TOWER
WOOD
GETMAN
HOKE
FIVE MILE POINT
MORRIS
DRAKE
CLARK
KEESE
Susquehanna R.
COOPERSTOWN

FIG. 118.

very important part of the preliminary operations. The selection should be so made that each point may command a view of the greatest practicable number of surrounding trigonometrical point objects, and that each angle at the point shall be as near as may be 60°. A triangle which has an obtuse or a very acute angle will experience a greater change of form, for a given error, than one which is nearly equilateral; and since the accuracy of each triangle depends upon the preceding ones, it is evident that the introduction of a single "ill-conditioned" triangle might vitiate the whole survey. No angle less than 30° or more than 120° should be used; and even such angles should not be admitted when the locality can be so chosen as to prevent it.

245. If the triangulation is to be over a limited extent of country which has already been covered by a net-work of Primary Triangles, a side of one of these triangles should be used as a base. It is never good practice to measure a base line, when a side of a triangle of a previous survey is available; but if no such side can be obtained, then the selection of a proper site for a base-line forms one of the first objects of the preliminary reconnaissance. It should, if possible, be fixed on an open plain, free from surface encumbrance or freed from such. It must be so chosen that the surrounding signals may be distinctly seen from its extreme points; and hence those signals which mark points of the adjacent triangulation, should be selected with reference to the base. The length of the base should be suited to the magnitude of the survey.

246. In measuring a base-line, every possible precaution should be taken to insure accuracy. The line measured should be straight, to effect which it should be ranged out with the transit. The ends of the base should be marked by a stone sunk in the ground, with a copper bolt let into it and the exact point of beginning and ending fixed by the intersection of two lines cut into the head of the bolt.

The measurement may be made with steel tape or rods. If a tape is used, it should be carefully drawn out each time to its standard length, and should be compared with a standard both before and after measurement, and correction made for its variation, if any, from standard. The mean of several measurements should be taken for the correct measurement. If the measurement has been made on an incline, instead of on a level, the measured distance should be reduced to the horizontal distance by multiplying the inclined distance measured by the cosine of the angle of inclination.

247. For a description of the base-line apparatus used in the U. S. Coast and Geodetic Survey, see Reports of that Survey for 1854, 1857, and 1880.

248. The alignment of the measuring tape, or rods, both vertically and horizontally, or in the line of the slope if the measurement be not horizontal, is of the greatest importance, since there is no compensation of errors, a faulty alignment always resulting in a measured length *greater* than the true length.

249. Having carefully measured the base, it is then necessary to reduce the measurement to the sea level.

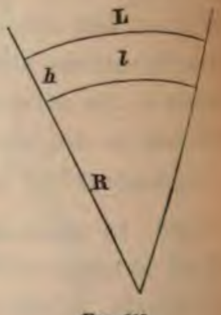


FIG. 119.

Let L = measured base.

Let l = reduced base.

Let R = radius of earth.

Let h = average height of measured base above sea level;

then, $l : L :: R : R+h;$

hence, $$l = \frac{LR}{R+h} = L\left(\frac{R}{R+h}\right) = L\left(1-\frac{h}{R+h}\right).$$

But h is so small as compared with R that we may, without ensible error, make $R+h=R$; whence we have,

$$l = L\left(1-\frac{h}{R}\right) = L - L\frac{h}{R}$$

250. The trigonometrical stations are marked by signals, hich may be constructed in a great variety of ways, depending pon the locality of the stations and the lengths of the sides of he triangles.

Sometimes a signal has to be raised above the level of the djacent country, in which case it is constructed of timbers, and pon the apex is placed a vertical staff bearing a flag. The xact trigonometrical point is determined by a plumb-line suspended from the apex of the signal.

A temporary signal may be constructed with hree or four pieces of scantling framed and raced, as shown in the annexed figure, with a short pole projecting from the apex. The plumb etermines the point B, which is the exact rigonometrical point over which the theodolite is o be placed. Where the sides of the triangles re not very great, a pole, planted vertically and urmounted by a flag, will answer as a signal.

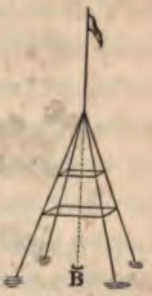


FIG. 120.

In order to distinguish the different signals, the flags which hey bear should be different from each other. They may be ormed by arranging stripes of white and red, according to some rearranged plan, and the flags of the different stations should e entered in a book. For the purpose of future reference, he trigonometrical point at each station, as B, should be indicated by a permanent mark. If the point falls upon a rock, a hole may be drilled to show the locality; or if not, a mark-stone may be sunk under the point, deep enough to be beyond the reach of accident. A record of the monument should be preserved, together with its reference to some of the permanent objects in the neighborhood.

251. A Heliotrope is necessary in long sights, and is always of great service in short sights in directing the observer to the station-mark. It consists essentially of a small mirror, so directed by an assistant as to throw a beam of sunlight into the telescope of the distant observer. Let a silvered glass, about 3 inches square, be mounted on a board in a manner similar to the telescope mount of a transit so as to have a motion about a horizontal axis and at the same time about a vertical axis; in front of this, at a distance of two or three feet, mount a board with a hole in it, across which hole threads are to be stretched at right angles to each other, and adjust this hole over the station by a plumb-line. At the centre of the back of the mirror scrape away the silver, making a small sight-hole; if now an assistant, sighting through the hole in the mirror, moves it so that the cross threads come in line with the distant station, it will be easy to keep the beam upon the observer by properly inclining and revolving the mirror. As the light reflected from so large a mirror would be too intense to observe with the telescope, it is necessary to make the cross-thread hole in the board quite small, not more than ½ inch diameter for distances not exceeding 5 miles, about one inch diameter for distances of ten miles, and so on.

A small pocket mirror will be found very useful as a means of telegraphing instructions, by combinations of flashes according to a system previously agreed upon. It can be directed to the observing station (or to the observed station) with sufficient accuracy for signalling, by setting a vertical staff in line with the distant station and causing flashes to travel up and down the staff.

252. The extent of the survey, and the standard of accuracy to which the results are required to conform, must determine the size and perfection of the instrument to be employed in the measurement of angles. The angles of the primary triangles of the United States Coast and Geodetic Survey are measured with theodolites, whose horizontal circles are 24 or 30 inches in diameter; and to eliminate, as much as possible, every source of error, great numbers of observations are made at each station, the readings being made on different points of the arc by different verniers. Usually from 40 to 60 observations are made for each angle—one measurement, with the telescope direct, and one with it reverted, constituting a complete observation. With these precautions, it has been found that the error in a primary triangle (where the sum of its three angles has been compared with 180°), has fallen much within 3 seconds. The error of 3 seconds has been adopted as the highest admissible limit of error in such triangles.

253. The theodolite does not differ essentially in the principles of its construction and use from the transit, which has already been described. It is fitted with many appliances, for accuracy in the observation and the reading of angles, which it is unnecessary to describe here. Fig. 121 is a representation of the 8 to 12 inch theodolite used in the U. S. Coast and Geodetic Survey, taken from the Report of that Survey for 1880.

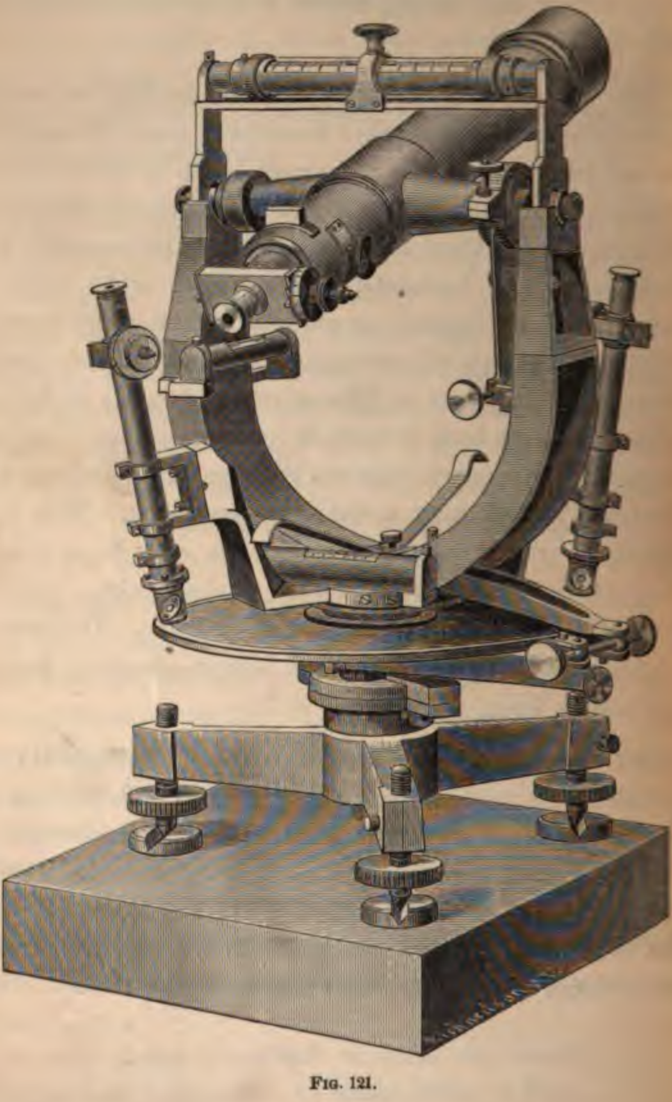


FIG. 121.

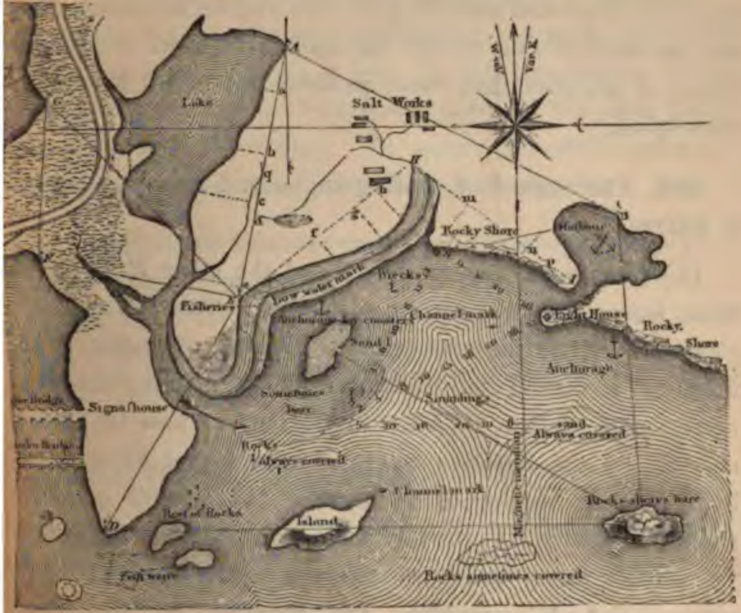


FIG. 122.

254. To illustrate the principle of repetition in the measurement of angles, suppose the 0 of the vernier to coincide with the 0 of the limb, and the telescope to be directed, from the station *A*, Fig. 122, upon one of the objects, as the signal at *B*. Clamp the limb and, unclamping the vernier plate, direct the telescope on the second object, as the signal at *E*. If we now clamp the vernier plate and, unclamping the limb, direct the telescope on the signal at *B*, the line (0°, 180°) of the limb will make with *AB* an angle equal to *BAE*. Again clamp the limb and, unclamping the vernier plate, direct the telescope n the signal at *E*. The reading will evidently be equal to wice the angle *BAE*; and if we repeat the operation, the eading will be three times the angle, and so on. After ten epetitions, if we add 360° each time the 0 of the vernier asses the 0 of the limb, the final reading will be ten times the angle BAE, affected with the joint errors of the ten observations, and one-tenth of this will be the reading required to a greater degree of accuracy than could probably be attained by a single observation.

255. The method of reading angles and recording notes is as follows:

(1.) First mark one vernier A and the other B by pasting these letters upon the vernier plate. Set vernier A at 0° and clamp it. Direct the cross-wires to the left of station B and then by a careful movement to the right bring the sight nearly upon station B, *being careful not to pass the station*, and perfect the bisection by the lower tangent screw. Read both verniers, reading B to minutes and seconds only, and make the entry as in the table subjoined. Now loosen the vernier clamp and turn carefully to the right till *nearly* upon station E, completing the bisection by the vernier tangent-screw. Now make a "check" mark in column "vernier A," as in table. Next loosen the lower clamp and turn the telescope to the right till station B is nearly reached, and repeat the previous operations, making "check" in "vernier A" column as before. In like manner repeat the operations for the third time, and enter the final reading upon station E, as in the table.

If the motion of vernier A has been *forward*, in the direction of the graduation of the limb, the first reading must be marked negative, as in the table; when the motion of vernier A is backward, the *final* reading must be marked negative. In the case just described the motion has been forward, therefore from the mean of the last readings (217° 15′ 15″), we subtract the mean of the first readings (0′ 10″), and divide the result by the number of repetitions (3) obtained for the mean angle 72° 25′ 1″.7.

(2.) Set vernier *A* at 180°, and having turned the telescope to the *right* of *E*, make three repetitions of the angle subtended by *EB*, working from *right* to *left*. In this case vernier *A* will pass over the 360° mark, which fact is noted in the table under the first "vernier *B*" reading. As vernier *A* worked backward, the *last* reading, that taken upon *B*, must be negative.

(3.) Revolve the telescope upon its horizontal axis, and turn the telescope about the vertical axis towards *B*. Set vernier *A* at 90° and repeat three times from *B* to *E*.

(4.) Set vernier *A* at 270° and repeat three times from *E* to *B*.

The final mean of the four angles is 72° 24′ 59″.2.

Both verniers are read to eliminate error of centering of graduated limb.

Repetitions are made to eliminate errors of graduation.

Readings from *left* to *right*, and from *right* to *left*, are taken to counteract errors due to torsion, and personal error of bisection.

The telescope is reversed on its horizontal axis to eliminate error due to inclination of horizontal axis, and error of collimation.

Angles taken at Station A, July 17, 1883.

Sta. Obs.	Vernier *A*.	*B*.	±	Calculation.	Mean Ang.
B	0° 0′ 0″	0′ 20″	—		
				217° 15′ 15″	
	✓ ✓ ✓			0 10	
				3)217 15 5	
E	217° 15′ 10″	15′ 20″			72° 25′ 1″.
E	180° 0′ 0″	0′ 10″			
				180° 0′ 5″	
				360	
	✓ ✓ ✓	360°		540 0 5	
				322 45 15	
				3)217 14 50	
B	322° 45′ 10″	45′ 20″	—		72° 24′ 56″.
B	90° 0′ 0″	0′ 0″	—		
				307° 14′ 50″	
	✓ ✓ ✓			90 0 0	
				3)217 14 50	
E	307° 14′ 40″	15′ 0″			72° 24′ 56″
E	270° 0′ 0″	0′ 20″			
				270° 0′ 10″	
	✓ ✓ ✓			52 45 5	
				3)217 15 5	
B	52° 45′ 0″	45′ 10″	—		72° 25′ 1′
					4) 99′ 56′
				Final mean.	72° 24′ 59

256. If several stations can be read in succession, a simple odification of the method is practicable. Suppose the observing ition to be *E* of Fig. 122, and we wish to read *A, H, B, C,* &c. ght *A* with the vernier set at 0°; unclamp the vernier and ırn to the right till *H* is bisected and enter the reading opposite [in the table below; unclamp the vernier and sight *B*, and nter its reading; continue the motion to the right, reading each tation in turn. Suppose *C* to be the station on the extreme ight; now set the vernier at 180° and work from *C*, around to he left, to *A*, entering the readings in the table in a reverse rder, from the bottom to the top of the page. Reverse the elescope, and with 90° as the first reading work from *A* to *C*, nd then with 270° as the first reading work from *C* to *A*. The otes are given below; the readings on station *A* subtracted from he corresponding readings on *H, B,* and *C*, give the angular istances of these points from the line *EA*.

Angles taken at Station E.

ta.	Vernier *A*.	*B*.	Mean Read.	Angles with Line *EA*.	Mean Angles with *EA*.
A	0° 0′ 0′	0′ 20″	0° 0′ 10″		
	72 0 10	0 0	72 0 5		
	90 0 0	0 10	90 0 5		
	162 0 20	0 10	162 0 15		
H	40° 0′ 10″	0′ 20″	40° 0′ 15″	40° 0′ 5″	
	112 0 0	0 10	112 0 5	40 0 0	
	130 0 10	0 30	130 0 20	40 0 15	
	202 0 10	0 10	202 0 10	39 59 55	40° 0′ 3″.75
B	66° 30′ 0″	30′ 20′	66° 30′ 10″	66° 30′ 0″	
	138 29 40	30 20	138 30 0	66 29 55	
	156 29 40	30 10	156 29 55	66 29 50	
	228 30 0	30 0	228 30 0	66 29 45	66° 29′ 52″.5

Sta.	Vernier *A*.	*B*.	Mean Read.	Angles with Line *EA*.	Mean Angles with *EA*.
C	108° 0′ 0″	0′ 10″	108° 0′ 5″	107° 59′ 55″	
	180 0 0	0 20	180 0 10	108 0 5	
	198 0 10	0 10	198 0 10	108 0 5	
	270 0 0	0 10	270 0 5	107 59 50	107° 57′ 58″.75

Having found by these methods the angles of any triangle, one of its sides being the base-line or a known side of a triangle already computed, we can find the sides of the new triangle.

First subtract the sum of the angles from 180° and apply $\frac{1}{3}$ of the error to each angle; next treat the triangle as a plane triangle and compute the two required sides.

257. The spherical excess in triangles of a Primary System is seldom more than about 6″, and triangles whose sides are not more than ten miles long may be regarded as plane triangles without sensible error.

258. It sometimes happens that a steeple, tower, or other prominent object must be used as a station, and in most cases it is impossible to set the instrument over the centre of such station. In such cases a "reduction to the centre" is necessary.

Let O be the position of the instrument, C the centre of a circular tower which marks the station, and DCG the desired angle, D being the right-hand object and G the left-hand one. Measure (in some one of the many ways for indirect measurement) the distance $OC = r$, and take the angle $GOC = y$, always measuring the angle y (called the angle of direction) from the left-hand object,

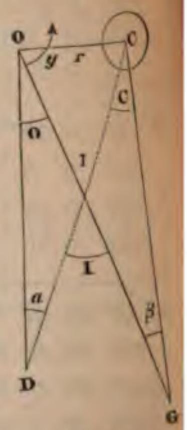


FIG. 123.

d estimating it towards the left, from 0° to 360°, as in the . The angle I being exterior to the triangle DOI we have $)+a$, and from the triangle GIC we have $I = C + \beta$, which we deduce

$$C = O + (a - \beta) \tag{1}$$

e now need to determine the correction $(a - \beta)$. In riangle DOC we have (calling the side DC, D) $\sin a = \frac{(O+y)}{D}$ (Art. **32**), or as a is, in practice, always very small ay substitute for its sine its value in seconds, making sin $a)'' \sin 1''$, which substituted above gives $(a)'' = \frac{r \sin (O+y)}{D \sin 1''}$. ke manner (calling the side GC, G) we have $(\beta)'' = \frac{y}{1''}$. Substituting these values in formula (1), we obtain

$$C = O + \left\{ \frac{r \sin (O+y)}{D \sin 1''} - \frac{r \sin y}{G \sin 1''} \right\}. \tag{2}$$

his formula is general if care is taken to estimate the angle h reference to the positions of the stations D, G, and C, as directed, the *signs* of the trigonometric functions also observed (see Davies' Leg., Trig. Art. **58**).

he angle O is measured in the usual manner. The angle y, e case supposed, is obtained by measuring the angle which tangent to the tower through O makes with the line OG, aking their half sum.

formula (2) the sides D and G are unknown. In triangles sides are not less than 3000 feet, r being relatively very , it will be sufficient to calculate these sides from the known and the uncorrected observed angles, and substitute such uted values in formula (2).

hen the sides are less than 3000 feet, r being relatively the values of D and G are obtained by two approximations. plot a triangle O' D' G' upon as large scale as practicable, using the known side and the *observed* angles; then plot the angle y, and lay off $O'C' = nr$, n being either 10, 20, 30, &c., so that nr may measure between $\frac{1}{10}$ and $\frac{1}{30}$ of the length of the shorter of the two plotted sides $O'D'$ and $O'G'$, in which case the plotted angle $O'D'C'$ will be equal to $n \times \alpha$, or $\alpha = \frac{O'D'C'}{n}$, and $\beta = \frac{O'G'C'}{n}$. These values substituted in formula (1) give a value of C which may be used in the computation of the sides D and G, and these computed values of D and G must then be substituted in formula (2).

259. An error of observation may also arise from the unequal illumination of the face of the object presented to the observer, called error due to phase; thus, if an observer at A sight a tower at D, the sun being in the direction S, he will direct his telescope to d, the middle of the illuminated portion, instead of to D. This error, and also that due to irradiation in the case of ordinary signals, may be avoided by observing when the sun is obscured, or by throwing a shadow upon rods and other commonly used signals. It is hardly worth while to introduce a formula for correction of phase in this connection.

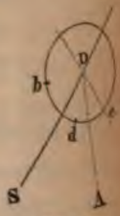


FIG. 124.

(For the methods used in the work of the U. S. Coast and Geodetic Survey, see "Field Work of the Triangulation," 1877, by Richard D. Cutts, assistant.)

260. When, in connection with a trigonometrical survey on shore, a harbor is to be surveyed (see Fig. 122), for the purpose of ascertaining the channels, their depth and width, the positions of shoals, and the depth of water thereon, other means must be used, and other examinations made, in addition to those already described.

Let buoys be anchored on the principal shoals and along the edges of the channel; and using any one of the lines already determined as a base, let the angles subtended by lines drawn from its extremities, to the buoys respectively, be measured with the theodolite. Then, there will be known, in each triangle, the base and the angles at the base, from which the distances to the buoys are easily found; and hence, their positions become known.

Having made the soundings and ascertained the exact depth of the water at each of the buoys, several points of the harbor are established, at which the precise depth of the water is known; and by increasing the number of the buoys, the depth of the water can be found at as many points as may be deemed necessary.

261. If a person with a theodolite, or transit, be stationed at each extremity of the base-line, it will not be necessary to establish buoys. A boat, provided with an anchor, a sounding-line, and a signal-flag, has only to throw the anchor, hoist the signal-flag, and make the sounding, while the persons at the extremities of the base-line measure the angles. From these data, the precise place of the boat can be determined.

262. There is another method of determining the places at which the soundings are made, that admits of great despatch, and which, if the observations are made with care, affords results sufficiently accurate.

Having established, trigonometrically, three points which can be seen from all parts of the harbor, and having provided a sextant, let the sounding be made at any place in the harbor, and at the same time the three angles subtended by lines drawn to the three fixed points, measured with the sextant.

The problem, to find, from these data, the place of the boat at the time of the sounding, is the same as Example 6, Art. **203**.

It is only necessary to measure two of the angles, but it is safest to measure the third also, as it affords a verification of the work.

The great rapidity with which angles can be measured with the sextant by one skilled in its use, renders this a most expeditious method of sounding and surveying a harbor.

For description of the sextant and its method of use, see Appendix B.

263. There is yet another method of finding the soundings, which, although not as accurate as those already explained, will, nevertheless, afford results approximating nearly to the truth. It is this:—Let a boat be rowed, with uniform speed, across the harbor, from one extremity to the other of any of the lines determined trigonometrically. Let soundings be made continually, and let the precise time of making each be carefully noted. Then, knowing the length of the entire line, the time spent in passing over it, as also the time of making each of the soundings, we can easily find the points of the line at which the several soundings were made; and hence, the depth of water at those points becomes known.

264. If a person stationed on shore with a theodolite or transit, takes the bearing of the boat, at every second or third sounding, determined by hoisting a flag, it will fix the positions of the soundings with great accuracy. Soundings may thus be made along any number of known lines, and a comparison of the depths found, on different lines, at or near their points of intersection, will show with what degree of accuracy the work has been done.

Sounding-lines should be made of strong cord, and divided into feet or fathoms, by different colored rags or other marks. The lead is shaped like the frustum of a cone, with the base *B* hollowed out to hold some grease. The land or mud of the ottom adheres to the grease, and thus shows the nature of the ottom, which should be entered in the field-ook, and laid down upon the map. As the ord is liable to change its length, it should e compared, from time to time, with some tandard. In tide-waters, the exact time of each sounding is to be noticed, and an assistant should note the height of the tide at regular intervals, upon a tide-gauge. The tide gauge is permanently placed at some convenient point of the harbor, and its 0 point is referred, by means of a spirit-level, to some fixed bench-mark, on a level with mean low-water mark, to which all the soundings must be reduced.

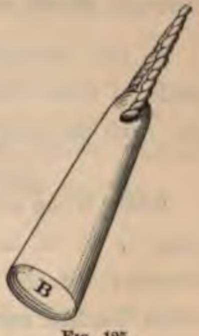


FIG. 125.

265. Having plotted the work done with the theodolite or transit, as also the outline of the harbor traced with the compass, t remains to delineate the bottom of the harbor; and this is done by means of horizontal curves, hereafter explained (Art. **332**), which are used to represent broken or undulating ground.

Let the plane of reference be taken through low-water mark, or to coincide with the surface of the water at low tide. The accuracy with which the bottom of the harbor is to be delineated, will guide us in fixing the distance between the horizontal planes of section.

The first horizontal plane should be passed at a distance below the shallowest point that has been sounded, equal to the number of feet fixed upon for the distance between the planes of section; and the curve, in which it intersects the bottom of the harbor, determined as in Art. **335**. And similarly, for the other horizontal planes of section.

Having thus delineated the bottom of the harbor, and noted on the map the distance of each intersecting plane below the plane of reference, let such lines be drawn as will indicate the channels, shoals, sunken rocks, and direction of the current.

In the example given in Fig. 122, soundings have been made in three directions, from the sand-bar in the harbor, and also from the rocky shore across to the light-house.

266. When a large extent of territory, or a long line of sea-coast is to be surveyed, it becomes necessary to consider the curvature of the earth's surface; this branch of surveying is called *Geodetic* surveying.

The operations necessary to the successful execution of a Geodetic Survey, require the minutest attention, and when performed, numerous corrections are to be applied to the measured lines and angles, on account of the various causes of error incident to such operations.

To investigate those causes of error, and to deduce rules for correcting the errors, in all cases, would exceed the limits of this treatise. We have, therefore, attempted nothing more than an outline of the operations in a trigonometrical survey, in which the Plane-Table and Compass are used in connection with the Theodolite or Transit, and in which the curvature of the earth is not considered.

SECTION II.

FILLING UP THE SURVEY.

After the triangulation is completed, the interior may be led up by the aid of the Compass, or Plane-Table, or both.

By the Compass.

267. The use of the compass, in determining points and lines, means of offsets, has been already explained (Art. **123**). We ill apply these principles in the example of the harbor, Fig. 122.

Place the compass at *A*, and take the bearing of the line *E*, which is S 12° W.

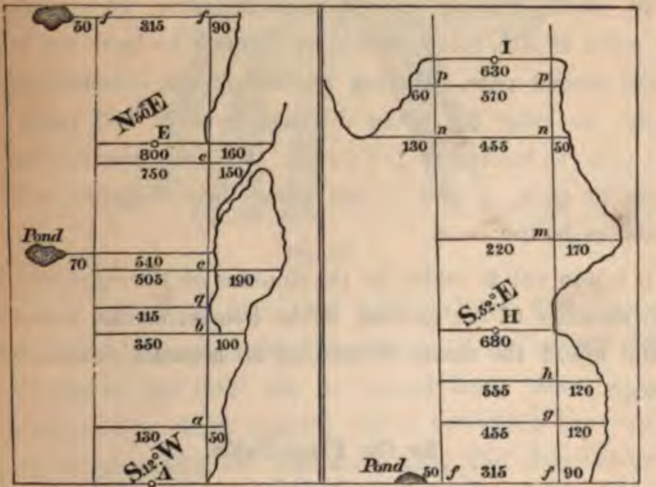


Fig. 126.

Enter this bearing at *A*. Then measure along the line *AE* ny distance, as *Aa* equal to 130 yards, and make an offset to he lake, which we measure and find to be 50 yards. Enter e 130 in the middle column, and as the lake lies on the right (in going from *A* to *E*), we insert the 50 in the right-hand column.

We then measure along the line *AE* to *b*, 350 yards from *A*. Here we make a second offset to the lake, and find it to be equal to 100 yards. Having entered the distances in the notes, we measure to *g*, the point where the line *AE* touches the creek, and we enter the distance from *A*, 415 yards.

At *d*, we lay off an offset on the left, to the pond, 70 yards; at *e*, an offset to the mouth of the creek, 150 yards; and at *E*, where the course terminates, an offset to the lake, of 160 yards. The entire distance from *A* to *E* is 800 yards.

At *E*, we take the bearing to *H*, which is N 50° E. Having measured along this line to *f*, 315 yards, we make an offset to the pond, on the left, of 50 yards, and to the shore, on the right, of 90 yards. Having entered these distances, we recommence the notes at 315, below, which we suppose to be at the bottom of the second page. Having reached *H*, the extremity of the course, we enter the entire distance from *E*, 680 yards. We next take the bearing to *I*, S 52° E. We then measure the distances to *m*, *n*, *p*, and *I*, and enter them, together with the offsets, as in the notes.

It is also well to make, in the columns on the right and left, such sketches of the ground, fields, houses, creeks, and rivers, as will afford the means of making an accurate delineation on paper.

By the Plane-Table.

268. The plane-table, Fig. 127, consists of two parts: a rectangular board, and a tripod to which it is firmly secured.

Directly under the rectangular board are four milled screws ch pass through sockets inserted in a horizontal brass-plate; are worked against a second horizontal plate, for the purpose of leveling the table; the table having a ball-and-socket motion, similar to the limb of the transit.

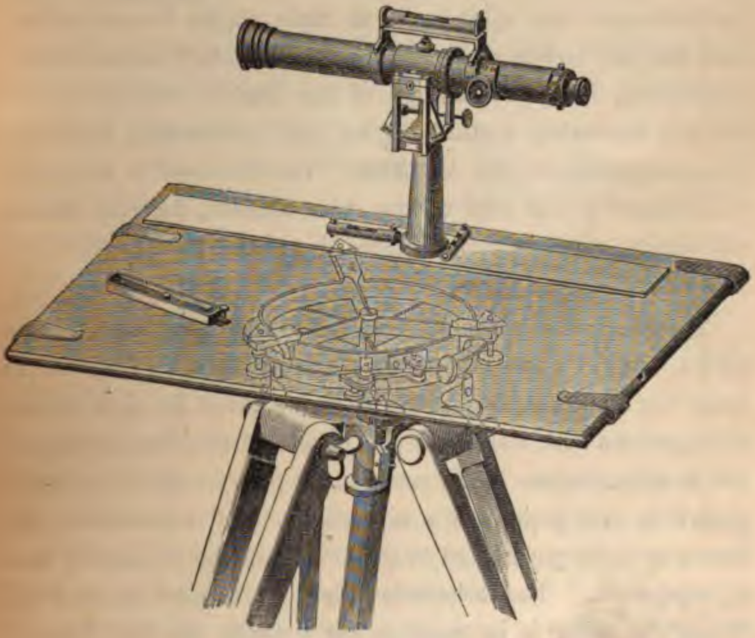


FIG. 127.

Between the upper horizontal plate and the table, there is a clamp-screw, similar to the clamp-screw of the transit, which being loosened, the table can be turned freely about its axis. There is, also, a small tangent screw, by which the smaller motions of the table are regulated, after the clamp-screw is made fast.

A set of brass clamps for fastening the paper to the table; a clamp with an attachment on one side for fastening a plumb-line, and, on the other, a pin immediately over the point of attachment *of the plumb-line*, for marking on the paper a point directly over a station of the ground; an Alidade and a Declinator accompany the Plane-Table.

The Alidade is a brass ruler, from one to two feet long, with a fiducial or true straight edge. On the upper face of the ruler are two spirit-levels at right angles to each other, and, near the middle of the ruler, a brass standard which carries a telescope, like the telescope of the transit, with a vertical arc for measuring vertical angles, and micrometer wires for measuring distances (see Art. **206**). The telescope is so placed with regard to the edge of the ruler beneath, that its line of collimation, when properly adjusted, is parallel to that edge and in the same vertical plane.

The Declinator is a metal box, containing a magnetic needle with a range of about 10° on each side of the 0. It is used to *orient* the table, *i. e.*, to place it at any point of the field in the same position with respect to the points of the compass that it had at other stations in the same survey; or, in other words, to place it in such position at a new station that a line previously drawn upon the paper shall be parallel to the line of sight which it represents. The orientation may be effected as follows: While the table is in position for drawing the first lines of the survey, place upon it the declinator, with one of the longer edges of its box set along a line drawn on the paper for the purpose, and note the reading of the needle; when the table is removed to a new position, turn it till the declinator, placed along the line as before, gives the same reading. Figure 127 represents the plane-table and its accompaniments as used on U. S. Coast Survey.

269. The plane-table is used to determine the shorter lines of a survey in extent and position.

Having placed a paper on the table, examine the objects and lines which are to be determined, and select for a base such a line of the triangulation that most of the objects can be seen from its extremities. Then place the plane-table over one extremity of the base; make it truly horizontal, and turn it until the larger part of the paper lies on the same side of the base with the objects.

Then, tighten the clamp-screw, and mark with a pointed pin the point of the paper directly over the station, which point is determined most accurately by suspending a plumb from the lower side of the table. Press the pin firmly on this point, bring the fiducial edge of the ruler against it, and sight to the other extremity of the base-line, and mark, with the pin or pencil, the direction of the line on the paper. Sight, in like manner, to every other object, and draw on the paper the corresponding lines, numbering them from the base-line, 1, 2, 3, 4, &c.

Then, with a pair of dividers, take from the scale a certain number of equal parts, to represent the base, and lay off the distance on the base-line from the place of the pin. Take up the table, carry it to the other extremity of the base, and place the point of the paper corresponding to that extremity, directly over it. Place the fiducial edge of the ruler on the base-line, and turn the table, by means of the tangent screw, until the sights are directed to the first station. If, however, in bringing the table to this position, the corresponding point of the paper has been moved from over the extremity of the base-line, move the legs of the tripod until it is brought back to its place. Let the table be then leveled, after which, place the ruler again on the base-line, and bring the table to its proper position, by the tangent-screw, and continue the adjustment until the extremity of the base-line, on the paper, is directly over the station, and in the same vertical plane with the base-line, on the ground. Then direct the sights to all the objects sighted to, from the other station, and mark the lines 1, 2, 3, 4, &c., from the base-line, as before. The intersections of the corresponding lines 1,1, 2,2, 3,3, 4,4, &c., determine, on the paper, the positions of the several objects, and a reference of these lines to the scale of equal parts, determines the true distances.

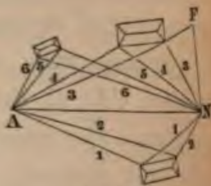


FIG. 128.

270. Let it be required, for example, to determine, by means of the plane-table, the relative positions of several houses.

From station *A*, and on one of the lines of the triangulation, as *AB*, measure the base-line *AN*, which we will suppose equal to 300 yards. Place the plane-table at *A*, and sight to the corners of the houses, and mark the lines 1, 2, 3, 4, &c. Then remove the table to *N*, and sight to the same corners as before, and draw the lines as in the figure. The points at which they intersect the corresponding lines, before drawn, determine the corners of the houses. The front lines of the houses may then be drawn on the paper. Draw lines at right angles to the front lines, and on them lay off the depths of the houses, with the same scale as that used for the base line.

To find the length of any line drawn on the paper, as the line 1, drawn through *A*, for example, place the dividers at *A* and extend them to the other extremity of the line, and then apply the line to the scale. The length of the line 1 is equal to 198 yards.

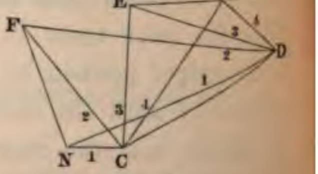


FIG. 129.

271. In this example, we determine from the base-line *CD*, the positions of the points *F*, *E*, and *H*.

273. For further description of the plane-table and its use, see "A Treatise on the Plane-Table and its use in Topographical Surveying," by E. Hergesheimer, U. S. Coast and Geodetic Survey, Report for 1880, Appendix No. 13.

◆

SECTION III.

PLOTTING THE TRIANGULATION.

The sides of the triangles having been completed, the work may then be plotted, as already explained, either by means of the circular protractor, or by the method of chords.

The Circular Protractor.

274. This instrument consists of a brass circular limb, Fig. 131, of about six inches in diameter, with a movable index *AB*, having a vernier at one extremity *A*, and a milled screw at the other extremity *B*, with a concealed cog-wheel that works with the cogs of the limb, and thus moves the index *AB* about the centre of the protractor. At the centre of the protractor is a small circular glass plate, on which two lines are cut; the point of their intersection is the exact centre of the instrument. The limb is generally divided to half-degrees; the degrees are numbered from 0 to 360.

At the 0 point, and at the opposite extremities of the diameter passing through that point, are small lines on the inner edge of the limb; the two extremities of the diameter, perpendicular to this latter, are designated in the same way.

Two angular pieces of brass, each having a small and sharp steel pin at its extremity, are fastened to the index, and revolve freely around the lines *ab* and *cd*. The small screws,

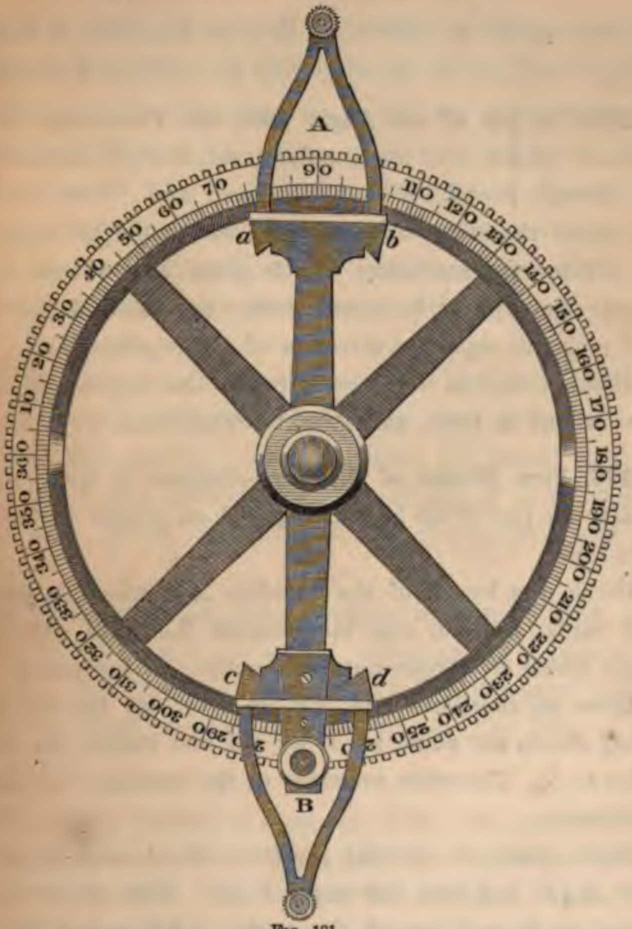


Fig. 131.

b, *c*, and *d*, move them in the directions of the lines *ab*, *cd*, the purpose of bringing the steel pins exactly into the line ich passes through the 0 of the index and the centre of protractor.

To adjust them to their places, place the centre of the pro-ctor over a marked point, and the 0 of the index to the 0 the limb. Then mark the place of the index by the pins; er which, turn the index 180°, and see if the pins will mark the same points as before. If they do, the index is adjusted; if they do not, correct the error with the screws a, b, c, and d.

275. To lay off an Angle with the Protractor.—Let its centre be placed over the angular point, and the diameter passing through 0 and 180°, on the given line. Turn the screw that works the index, until the 0 of the vernier coincides with the division corresponding to the given angle; then let the angular brass pieces be turned down; the points dotted by the steel pins will show the direction of the required line.

If this line does not pass through the angular point, the pins are out of place, and must be re-adjusted.

276. First Method of Plotting.—Suppose it were required to make the plot of the harbor, Fig. 122, on a scale of 450 yards to an inch.

Divide the length of the base-line AB, which is equal to 1140 yards, by 450, and the quotient 2.53 will express the length which is to represent the base-line on the paper.

Draw an indefinite line AB, to represent the base; and having chosen any point, as A, for the first station, lay off 2.53 inches to B. The other extremity of the base-line will thus be determined.

Then, place the circular protractor at A, and lay off the angle BAE, and then the angle EAG. Next, place the protractor at B, and lay off the angles ABE and EBC. The intersection of the lines AE and BE will determine the station E. Let the protractor be then placed at this point, and all the angles of station E laid down.

The point G, where EG intersects AG, and the point C, where EC intersects BC, will then be found.

By placing the protractor at C and G, we can determine the points D and F, when the place, on the paper, of all the stations will be known.

To unite the work done with the compass, spread the compass-notes before you, and draw through *A* a line to represent the meridian. The course *AE* lies to the west of this meridian, and makes an angle of 12° with it.

Then, lay off from the scale the distances *Aa*, *Ab*, *Aq*, *Ac*, *Ad*, *Ae*, and at the several points erect perpendiculars to *AE*. Lay off, on these perpendiculars, the lengths of the offsets, and the curve traced through the points so determined, will be the margin of the lake.

At *E*, draw a parallel to the meridian through *A*, and lay down the course *EH*, which is easterly, and makes an angle of 50° with the meridian. Then, lay down the several distances to the offsets, and draw the offsets and lay off their lengths. Do the same for the course *HI*, and all the compass-work will be plotted.

The work done with the plane-table is united to the work done with the transit, by simply reducing it to the same scale, and then placing the line *AN* on the paper of the plane-table, upon the line *AN*, drawn on the plot of the triangulation.

277. Second Method of Plotting.—Place the centre of the protractor near the centre of the paper, and draw a line through the points 0 and 180°. This line will have the same position with the circular protractor that the base-line *AB* had with the limb of the transit.

Then lay off, from the 0 point, an arc equal to the direction from *A* to *E*, also an arc equal to the direction *AG*, and through the centre point, and the points so determined, draw lines. Lay off in succession, in a similar manner, the directions taken at all the stations; and through the centre point, and the points so determined, draw lines, and designate each by the letters of the direction to which it corresponds.

Now, since all the lines drawn on the paper have the same position with the circular protractor, as the corresponding lines on the ground have with the limb of the transit, it follows that each direction will be parallel to its corresponding line upon the ground.

Hence, any line may be drawn parallel to that passing through 0 and 180°, to represent the base-line *AB*. Having drawn such a line, and marked a point for the station *A*, lay off the length of the base, and the extremity will be the station *B*.

Through *A* and *B*, so determined, draw parallels respectively to the lines corresponding to the directions *AE* and *BE*, and the point of intersection will determine station *E*. Through *B* and *E*, draw parallels to the lines which correspond to the directions *BC*, *CE*, and their point of intersection will determine station *C*. Through *C* and *E*, draw lines parallel to the lines corresponding to the directions *CE* and *ED*, and the point of intersection will determine *D*. In a similar manner we may determine the stations *F* and *G*.

Method of Chords.

278. The chord of a given arc is equal to the sine of half the arc with double the radius.

For, let *DAF* be any given angle, and *AH* a line bisecting it. Let *DKC* be the chord of the arc *DC*, described with a given radius, and *HF* parallel to *CD*, the sine of half the given angle, to a radius $AF = 2\,AC$.

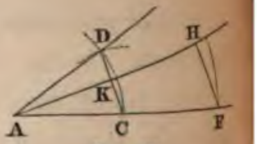


FIG. 132.

Since $AF = 2\,AC$, we have, from similar triangles, $HF = 2\,KC$; but $DC = 2\,KC$, hence $HF = CD$.

279. To lay off an Angle.—To avoid, as far as possible, the use of fractions, let us suppose the radius of the table of natural sines to be 1 *ten*, or 10 inches.

Take, from a scale, 5 equal parts, with which, as a radius, from the centre *A*, describe an arc *CD*. Take from the table the natural sine of half the arc, and remove the decimal point one place to the right; the result will express the sine of half the arc to the radius 10, or the chord of the arc to the radius 5. From the same scale, take this sine in the dividers, and from *C*, as a centre, describe an arc cutting *CD* in *D*; draw *AD*, and *CAD* will be the angle required.

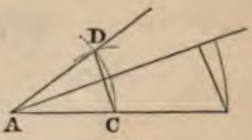


FIG. 133.

This is the most accurate of all the methods of laying off an angle, and it may also be applied advantageously to the second method of plotting, thus:

Draw a fine straight line, generally in the direction of the meridian or of the base-line of the survey; and also a line perpendicular to it. From the point of intersection, as a centre, with a radius of 5 equal parts of the scale, describe the circumference of a circle cutting the straight lines in the points marked 0 and 90°.

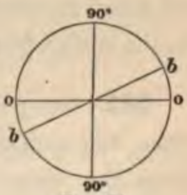


FIG. 134.

To lay off an angle, as, for instance, the angle 14° 29′. The half of it is 7° 14′ 30″, the natural sine of which is 0.126005, or 1.26 to the radius of 10 inches. Set off from 0 to *b*, as in the figure, this distance taken from the scale, and through the two points *b*, *b*, thus determined, draw a straight line. This line should pass through the centre, and will make with the line (0, 0) the angle 14° 29′; and any line on the paper drawn parallel to it, will make with the line (0, 0) the same angle. The further application is obvious.

BOOK VII.

LEVELING.

SECTION I.

DEFINITIONS AND PRINCIPLES.

280. **Leveling** is the art of determining the relative distances of points from the centre of the earth.

281. A line whose points are all equally distant from the centre of the earth, is called a line of *true level;* and a surface, all whose points are equally distant from the centre of the earth, as the surface of still water, is called a *level surface.*

282. One point is said to be above another, when it is farther from the centre of the earth; and this difference of distance from the centre, is called the *difference of level* between the two points.

283. A straight line drawn tangent to a line of true level, at any point, is a horizontal line, and is called the line of *apparent level.* Thus, Fig. 135, if C is the centre of the earth, and AEF a line of true level, ABD is the line of apparent level. This is the line of level determined by an instrument. The difference between the apparent and true level of the points A and E, is BE, the *excess* of the secant CB, of the arc AE, over the radius CE.

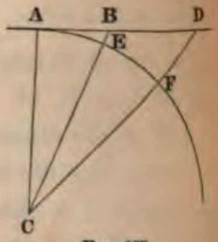


FIG. 135.

284. To find a general formula for computing this excess, we have (Geom., B. IV, Prop. XXX),

$$\overline{AB}^2 = BE(BE + 2EC);$$

but, since the arc AE is very small in comparison with the radius of the earth, the arc AE will not differ sensibly from the tangent AB; the diameter $2EC$ may, for the same reason. be taken for the secant $(BE+2EC)$; hence,

$$\overline{AE}^2 = BE \times 2EC, \quad \text{or, dividing by } 2EC,$$

$$BE = \frac{\overline{AE}^2}{2EC} \quad . \quad . \quad . \quad . \quad (1).$$

If we take the mean diameter of the earth to be 7919 miles, formula (1) gives

$$BE = \frac{\overline{AE}^2}{7919} \quad . \quad . \quad . \quad . \quad (2), \quad \text{hence,}$$

The departure of the apparent from the true level, starting from a given point, is equal to the square of the distance to the second point, divided by the diameter of the earth.

If, in formula (2), we give to AE, in succession, every value from 1 chain to any given number of chains (say 100), and reduce, at the same time, both terms of the fraction to inches, a table may be computed as on next page.

Observe, that when the distance $AE = 80$ chains $= 1$ mile, that BE is $= 8.001$ inches, or two-thirds of a foot, very nearly; and for any other distance, d, *in miles*, we have,

$$1^2 : d^2 :: \tfrac{2}{3} \text{ of a foot} : \tfrac{2}{3}d^2;$$

hence, we have the following easy rule for finding the correction of curvature in feet:

The correction for curvature, in feet, is equal to two-thirds of the square of the distance in miles.

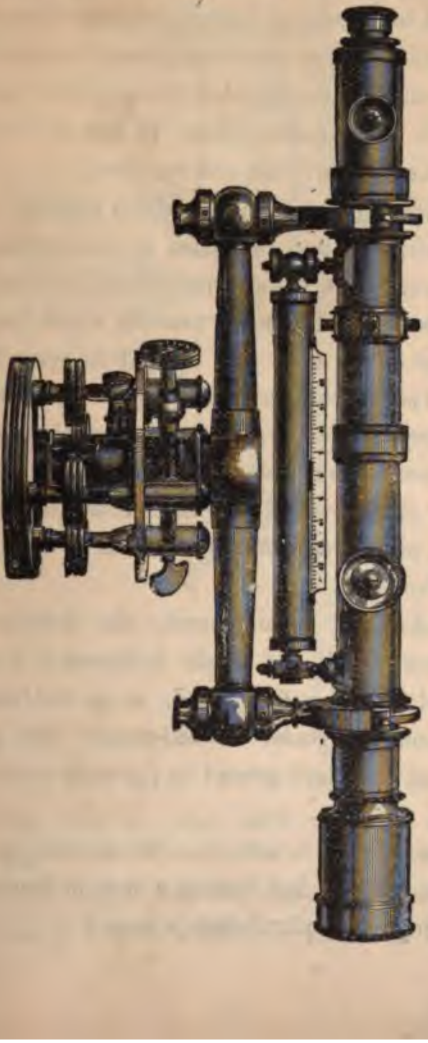
Table showing the differences, in inches, between the true and apparent level, for distances between 1 and 100 chains.

Chains.	Inches.	Chains.	Inches.	Chains.	Inches.	Chains.	Inches.
1	.001	26	.845	51	3.255	76	7.221
2	.005	27	.911	52	3.380	77	7.412
3	.011	28	.981	53	3.511	78	7.605
4	.020	29	1.051	54	3.645	79	7.802
5	.031	30	1.125	55	3.781	80	8.001
6	.045	31	1.201	56	3.925	81	8.202
7	.061	32	1.280	57	4.061	82	8.406
8	.080	33	1.360	58	4.205	83	8.612
9	.101	34	1.446	59	4.351	84	8.832
10	.125	35	1.531	60	4.500	85	9.042
11	.151	36	1.620	61	4.654	86	9.246
12	.180	37	1.711	62	4.805	87	9.462
13	.211	38	1.805	63	4.968	88	9.681
14	.245	39	1.901	64	5.120	89	9.902
15	.281	40	2.003	65	5.281	90	10.126
16	.320	41	2.101	66	5.443	91	10.351
17	.361	42	2.208	67	5.612	92	10.587
18	.405	43	2.311	68	5.787	93	10.812
19	.451	44	2.240	69	5.955	94	11.046
20	.500	45	2.531	70	6.125	95	11.233
21	.552	46	2.646	71	6.302	96	11.521
22	.605	47	2.761	72	6.480	97	11.763
23	.661	48	2.880	73	6.662	98	12.017
24	.720	49	3.004	74	6.846	99	12.246
25	.781	50	3.125	75	7.032	100	12.502

SECTION II.

INSTRUMENTS.

35. **The Y Level.**—*A Level* is an instrument used to ate a horizontal line, and also, to determine the difference vel of any two points on the surface of the earth.



20-INCH Y LEVEL.

FIG. 136.

The part of the instrument shown in Fig. 136, rests on a tripod, to which it is made fast, and on which it is leveled by means of two leveling plates, such as are described in the account of the Transit, Art. **177.**

The telescope rests on vertical supports called, from their shape, Y's or Wyes, and is confined in the wyes by loops or clips, which are fastened by tapering-pins.

The telescope has at each end a ring of bell-metal, turned very truly and both rings of exactly the same diameter; by these it revolves in the wyes, or can be at pleasure clamped in any position when the clips of the wyes are brought down upon the rings, by pushing in the tapering-pins. It has a rack and pinion movement to both object-glass and eye-piece.

A spirit-level or ground bubble-tube is attached to the under side of the telescope, and furnished at the different ends with screws for movement in both horizontal and vertical directions.

The level scale which extends over the whole length is graduated to tenths of an inch, and figured at every fifth division, counting from zero at the centre of the aperture of the tube through which the glass vial appears; the scale is set close to the glass.

The wyes are perpendicular to a level-bar, to which they are screwed fast; each wye has two nuts, both adjustable with the ordinary steel pin. Connected with the level-bar is the head of the tripod-socket.

The tripod-socket is compound; the interior spindle *D*, Fig. 137, upon which the whole instrument is supported, is made of steel, and nicely ground, so as to turn evenly and firmly in a hollow cylinder of bell-metal; this again has its exterior surface fitted and ground to the main socket *EE* of the tripod-head.

The bronze cylinder is held upon the spindle by a washer and screw, the head of the last having a hole in its centre, through which the string of the plumb-bob is passed.

upper part of the instrument, with the socket, may thus ached from the tripod-head; and this also can be un- l from the legs, so that both may be conveniently in the box.

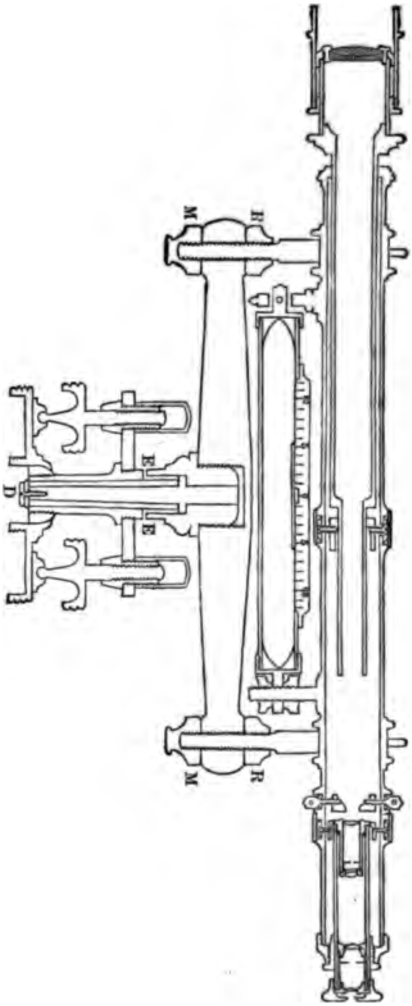


Fig. 137.

ittle under the upper parallel plate of the tripod-head, and main socket, *is a screw* which can be moved into a corres ponding groove, turned on the outside of the hollow cylinder, and thus made to hold the instrument in the tripod when it is carried upon the shoulders.

Before using the Level, it must be adjusted. The adjustment consists in bringing the different parts to their proper places.

The line of *collimation* is the axis of the telescope. With this axis, the line drawn through the centre of the eye-glass and the intersection of the cross-wires, within the barrel of the telescope, ought to coincide.

FIRST ADJUSTMENT.

To fix the intersection of the cross-wires in the axis of the telescope.

286. Having screwed the tripod to the instrument, extend the legs and place them firmly. Then loosen the clamp-screw and direct the telescope to a small, well-defined, and distant object. Then slide the eye-glass till the cross-wires are seen distinctly; after which adjust the object-glass to its proper focus, when the object and the cross-wires will be distinctly seen. Note now the precise point covered by the intersection of the cross-wires.

Having done this, revolve the telescope in the Y's half round, when the attached level will come to the upper side. See if, in this position, the horizontal wire appears above or below the point, and in either case, loosen the one and tighten the other of the two screws which work the horizontal wire, until it has been carried over half the space between its last position and the observed point; bring it the rest of the way by the leveling screws. Carry the telescope back to its place: direct again the intersection of the cross-wires to the point, and repeat the operation till the horizontal wire neither ascends nor descends while the telescope is revolved. A similar process will arrange the vertical wire, and the line of collimation is then adjusted.

SECOND ADJUSTMENT.

To make the axis of the attached level parallel to the line of collimation.

287. Turn the leveling-screws until the bubble of the level stands at the middle of the tube. Then open the loops and reverse the telescope. If the bubble still stands at the middle of the tube, the axis of the level is horizontal; but if not, it is inclined, the bubble being at the elevated end. In such case, raise the depressed or depress the elevated end by means of the small screw provided for the purpose, half the inclination; and then with the leveling screws bring the level to a horizontal position. Reverse the telescope in the Y's and make similar corrections again; and proceed thus until the bubble stands in the middle of the tube, in both positions of the telescope; the axis of the level is then horizontal.

Let the telescope be now revolved in the Y's. If the bubble continues in the middle of the tube, the axis of the level is not only horizontal, but also parallel to the line of collimation. If, however, the bubble recedes from the centre, the axis of the level is inclined to the line of collimation, and must be made parallel to it by means of two small screws, which work horizontally. By loosening one of them and tightening the other, the level is soon brought parallel to the line of collimation; and then, if the telescope be revolved in the Y's, the bubble will continue at the middle of the point of the tube. It is, however, difficult to make the first part of this adjustment, while the axis of the level is considerably inclined to the line of collimation; for, even if the level be truly horizontal in one position of the telescope, after it is reversed there will be but one corresponding position in which the bubble will stand at the middle of the tube. This suggests the necessity of making the first part of the adjustment with tolerable accuracy; then, having made the second with care, re-examine the first, and proceed thus till the adjustment is completed.

THIRD ADJUSTMENT.

To make the level and the line of collimation perpendicular to the axis of the instrument, or parallel to the level-bar.

288. Loosen the clamp-screw and turn the bar until the level comes directly over two of the leveling screws. By means of these screws, make the level truly horizontal. Then, turn the level 180° upon its vertical axis; if, during the revolution, it continue horizontal, it must be at right angles to the axis of the instrument about which it has been revolved. But if, after the revolution, the level be not horizontal, rectify half the error with the screws at *M* and *R*, Fig. 137, and half with the leveling screws. Then place the bar over the other two leveling screws, and make the same examinations and corrections as before; and proceed thus, until the level can be turned entirely around without displacing the bubble at the centre. When this can be done, it is obvious that the level and the line of collimation are at right angles to the axis of the instrument about which they revolve; and since the axis is carefully adjusted by the maker, at right angles to the bar, it follows that the line of collimation, the level, and the bar, are parallel to each other.

It is always necessary to examine the adjustments frequently, in order to secure satisfactory results.

LEVELING RODS.

289. The leveling rods are used to determine the points at which a given horizontal line intersects lines that are perpendicular to the surface of the earth, and to show the distances of such points of intersection from the ground.

There are three kinds of rods used by Engineers, known as the New York, Philadelphia, and Boston or Yankee rods. The Philadelphia Rod is divided to tenths, and reads to two-hundredths of a foot. The New York and Boston rods are divided to hundredths of a foot, and read by verniers to thousandths. They are all sliding rods.

290. New York Rod.—This rod, which is shown in Fig. 138, is cut in two parts so that both ends may be exhibited. It is made of maple or satin-wood, in two pieces, sliding one from the other, always in the same direction, so that the same end is always held on the ground, and the graduations start from that point.

The graduations are made to tenths and hundredths of a foot, the tenth figures being black, and the feet marked with a large red figure.

A target is used to indicate where the horizontal line cuts the rod.

The face of the target is divided into quadrants, by a horizontal and a vertical diameter; and these diameters are the boundaries of alternate colors with which the diagonal quadrants are painted.

The opening in the face of the target is a

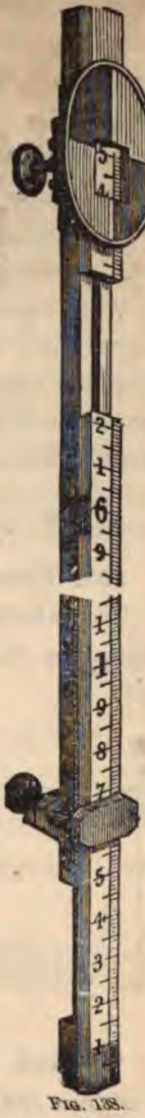


FIG. 138.

little more than a tenth of a foot long, so that in any position a tenth, or a foot figure, can be seen on the surface of the rod.

The right edge of the opening is chamfered, and divided into ten equal spaces, corresponding with nine-hundredths on the rod; the divisions start from the horizontal line which separates the colors of the face. The vernier reads to thousandths of a foot.

For heights less than six and a half feet, the target is moved along the sliding part, to which it is slightly attached by springs, and to which it may be permanently attached by a clamp-screw, and the reading is made by the vernier on the target.

When a greater height is required, the horizontal line of the target is fixed at that point, and the upper half of the rod, carrying the target, is moved out of the lower, the reading being now obtained by a vernier on the graduated side, up to an elevation of twelve feet.

TESTS OF ADJUSTMENT.

291. There is a method of testing the adjustments of the Y level, which ought not to be neglected, since all the results depend on the accuracy of the instrument. The method is this:

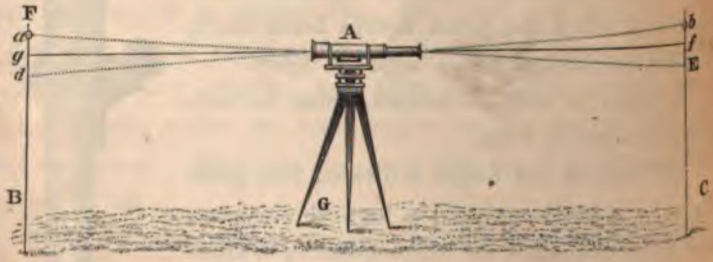


Fig. 139.

The level being adjusted, place it at any convenient point, as *G* (Fig. 139). At equal distances of about 300 feet in opposite directions from the instrument, drive two pegs firmly into the ground and take readings of the rod upon them. The difference of the readings will be the difference of level of the tops of the pegs, even though the level be out of adjustment. Now set the level at about 50 feet beyond either peg, nearly in line with them, and again take rod-readings upon them; the difference of these new readings, *corrected for curvature of the earth*, should equal the difference of level of the pegs as found before. If the readings are not what they should be, the adjustment may be perfected thus: Call the further peg *a*, the nearer peg *b*, and the position of the instrument *c*. (Fig. 140). Let *R* be the first reading at *a*, and *R'* that at *b*; let *r* be the second reading at *a*, corrected for curvature, and *r'* the corresponding reading at *b*, also corrected; let

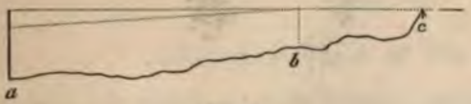


FIG. 140.

$$(R - R') - (r - r') = \pm D;$$

then we have

$$ab\ (= 600 \text{ ft.}) : ac\ (= 650 \text{ ft.}) :: \pm D : \pm d.$$

Add the correction *d* to *r*, and having set the target to this reading on *a*, bring the horizontal wire to coincide with it by the adjusting screws. See also that the bubble is in the middle of the run at the same time.

SECTION III.

LEVELING IN THE FIELD.

292. The operations of leveling may be undertaken.

1st. For the purpose of determining the difference of level between two given points;

2d. For the purpose of obtaining a section or profile along a given line, as in the preliminary surveys for railroads and canals;

And, as will be described hereafter,

3d. For the purpose of determining the contour lines in a topographical survey;

4thly. For the purpose of determining the volume of any given mass of earthwork or masonry; as the measurement of excavations and embankments for canals and railroads; and,

5thly. For the purpose of determining and indicating boundaries for filling and excavation; such as setting slope stakes, &c.

Difference of Level between Two Points.

293. When it is proposed to find the difference of level of any two objects, or stations, all levels made in the direction of the station at which the work is begun, are called, for the sake of distinction merely, *back-sights;* and levels taken in the direction of the other station, *fore-sights.*

Before going on the field with the level, rule three columns, as below, and head them, stations, back-sights, fore-sights.

FIELD NOTES.

Stations.	+ Back-Sights.	— Fore-Sights.
1	10	3
2	11.6	0
3	6.8	4.9
4	3.9	8.3
Sums	32.3	16.2
	16.2	
Dif. of level . .	16.1	

Find the difference of level between any two points, as A and G (Fig. 141).

294. The level being adjusted, place it at any point, as *B*, as nearly in the line joining *A* and *G*, as may be convenient.

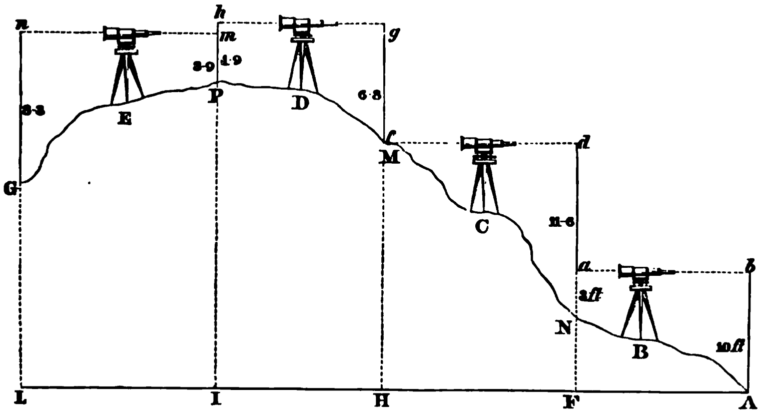


FIG. 141.

Place a leveling rod at *A*. Make the level horizontal by means of the leveling screws; turn the telescope to the rod at *A*, and direct the rodman to raise the target until the horizontal line *ab* pierces its centre; then note the distance *Ab* (equal to 10 feet in the present example) and enter it in the column of back-sights opposite station 1.

Send the rodman forward to some point, as *N*, in the proposed direction, and sight to the rod as before; enter the distance *Na*, equal to 3 feet, in the column of fore-sights opposite station 1 (*B*). Then remove the level to a convenient point, as *C* (2). Direct the rodman to run up the vane to the proper height; then make the back-sight, and enter it, $Nd = 11.6$ feet, in the column of back-sights, opposite station 2. Let the rodman then be sent forward to a convenient point, as *M*, and make the fore-sight to *f*; and enter $Mf = 0$, in the column of fore-sights, opposite station 2 (*C*). Remove the level, in succession, to *D* and *E*, and make similar levels at those points, and enter the results in the column of back-sights and fore-sights, opposite station 3 (*D*), and 4 (*E*).

It is evident from the figure, that the difference of level *NF*, between *A* and *N*, is equal to the back-sight *bA*, diminished by the fore-sight *aN*; also that the difference of level between *N* and *M*, is equal to the back-sight *dN*, diminished by the fore-sight 0, and since each set of observations is entirely independent of every other set, we may infer that *the difference of level between two consecutive points, as determined by the same position of the level, is equal to the back-sight, diminished by the fore-sight.* If the fore-sight is greater than the back-sight, the difference will be affected with a *minus* sign, a result which shows that the second point is lower than the first; and,

Generally, *the difference of level between any two points, determined as above, is equal to the sum of the back-sights diminished by the sum of the fore-sights.* If the result is plus, the second point is higher than the first; if negative, it is lower.

In the example given, the difference of level between *A* and *G*, is 16 feet and 1 tenth.

295. In the above example, we did not regard the difference between the true and apparent level. If it is necessary to ascertain the result with extreme accuracy, this difference must be considered; and then, the horizontal distances between the level, at each of its positions, and the rods, must be measured, and the apparent levels diminished by the differences of level; which differences can be found from the table.

EXAMPLE.

Stat.	Back-sts.	Distances.	Fore-st.	Distances.	Cor. back-sts.	Cor. for-sts.
1	9.8	20 ch.	1.6	32 ch.	9.7583	1.4933
2	8.7	25 ch.	2.4	28 ch.	8.6349	2.3183
3	5.2	18 ch.	3.1	16 ch.	5.1663	3.0734
4	10.3	29 ch.	1.9	87 ch.	10.2124	1.1115
5	11.0	45 ch.	2.5	72 ch.	10.7891	1.9600
					44.5610	8.9565

In this example, the first column shows the stations; the second, the back-sights; the third, the distances from the level in each of its positions to the back rod; the fourth, the fore-sights; the fifth, the distances from the level to the forward rod; the sixth and seventh, are the columns of back and fore-sights, corrected by the difference of level. The corrections are thus made: The difference of level in the table corresponding to 20 chains, is 5 tenths of an inch, or .0417 of a foot nearly; which being subtracted from 9.8 feet, leaves 9.7583 feet for the corrected back-sights; this is entered opposite station 1 in the sixth column. The difference of level corresponding to 32 chains, is 1.280 inches, or .1067 feet, nearly; which being subtracted from the apparent level, 1 foot 6 tenths, leaves 1.4933 feet, for the true fore-sight from station 1. The other corrections are made in the same manner.

The sum of the back-sights being 44.5610 feet, and the sum of the fore-sights 8.9565 feet, it follows that the difference, 35.6045 feet, is the true difference of level.

296. In finding the true from the apparent level, we have not regarded the effect caused by refraction on the apparent elevation of objects, as well because the refraction is different in different states of the atmosphere, as because the corrections are for short distances inconsiderable. The error occasioned by refraction is opposite to, and tends to diminish, the error occasioned by the curvature of the earth. If desired, it may be corrected by diminishing the effect of the earth's curvature by one-seventh of itself.

297. The small errors that would arise in regarding the apparent as the true level, may be avoided *by placing the leveling rods at equal distances from the level.* In such case, it is plain, 1st, that equal corrections must be made in the fore and back-sights; and, 2dly, that when the fore and back-sights are diminished equally, the result, which is always the difference of their sums, will not be affected.

This method should always be followed, if practicable, as it avoids the trouble of making corrections for the difference of true and apparent level.

The differences between the true and apparent level, being very inconsiderable for short distances, if only ordinary accuracy is required, it will be unnecessary to make measurements at all. Care, however, ought to be taken, in placing the leveling rods, to have them as nearly *equidistant from the level,* which can be effected by the rodman, by pacing the distance from back-sight rod to level, and from level to fore-sight rod; and if the distances are unequal, let the next distances also be made unequal; that is, if the back-sight is the longer in the first case, let it be made proportionably shorter in the second, and the reverse.

SECTION IV.

SECTION LEVELING.

298. In the surveys which precede the construction of roads, railroads, canals, dikes, or other similar earthworks, the surveyor must make such measurements as are necessary to enable him to estimate the volume of the material to be removed. In addition, therefore, to the horizontal measurements made in connection with the *location* of the work, vertical dimensions, or heights, are also necessary, and are taken at every important change in the inclination of the surface along the line of the survey.

These heights are taken by the level and rod, and are simply vertical distances of points along the surface above an assumed level line called the *datum* line.

299. In the survey of a long line of railway or canal, one of whose termini is in the vicinity of tide-water, the datum line is usually assumed at the level of mean high-water. In cases of surveys entirely inland, the datum line is taken at some convenient depth below the beginning point of the survey, and at such a distance that it shall be below the entire line on the surface. For such surveys, the system of notes described in the preceding section is insufficient.

300. As the survey progresses, fixed points of reference, called *benches*, are located in the vicinity of the line. Permanent objects are usually selected for benches; such as rocks, buildings, or trees, and at such distances from the line of the work as to be undisturbed by the subsequent construction.

301. Temporary benches, employed merely while changing the position of the leveling instrument, are called *turning points.* In either case, a well-defined point must be provided—one not easily disturbed by a blow, and, moreover, one upon which the rod can be held vertically.

302. In order to understand the field operations and the mode of keeping notes, it will be necessary to comprehend the principle involved in all leveling practice.

Suppose that the depths of different points of the bottom of a shallow lake are required; these could be readily obtained by measuring the distances from the surface of the water to the bottom by means of a sounding line, or in winter by cutting holes in the ice and measuring the distances to the bottom with a pole.

In this illustration the various points on the bottom are located with reference to the plane of the surface of the water.

The practice of leveling is identical in principle. The horizontal surface of reference, from which to deduce relative heights, is generated by the line of collimation as the telescope is revolved about the vertical axis, and the "soundings" to points below this plane of reference are made with a leveling rod, whose lower end rests upon the point to be located, and whose target is moved so that the plane of reference shall cut its horizontal line.

When the instrument is set up at a new station, the distance of its new plane of reference above or below the previous one, must be determined in order to secure continuity of the work.

303. The following example will exhibit the method of recording the [illegible] of a sec[illegible] The datum line is assumed to be th[illegible]nch. When the field-book is of the ordinary pocket size, the seven columns of notes will generally occupy two opposite pages; the first five being upon the left-hand page.

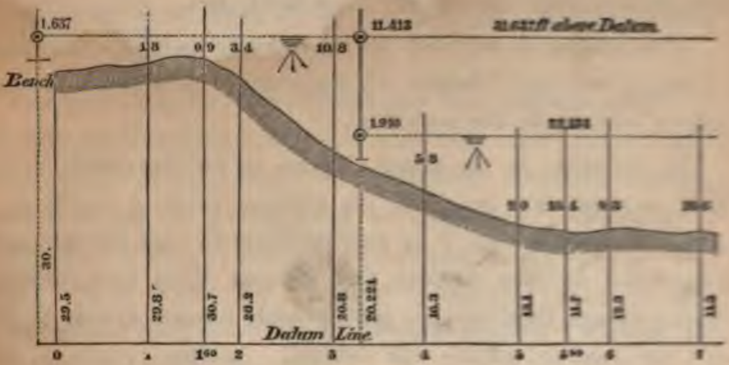


FIG. 142.

Dist.	+ Sight.	Ht. of Ins.	− Sight.	Surface Height.	Grade Height.	Remarks.
Bench.	1.637	31.637		30.		Bench on top of fence-post 30 ft. north of 0 stake.
0			2.1	29.5		
1			1.8	29.8		
1^{60}			0.9	30.7		
2			3.4	28.2		
3			10.8	20.8		
T. P.	1.910	22.134	11.413	20.224		
4			5.8	16.3		
5			9.0	13.1		
5^{50}			10.4	11.7		
6			9.8	12.3		
7			10.6	11.5		

The bench having been selected and marked, its location is described in the column of remarks.

The level is adjusted in some convenient place in the vicinity, and the reading of the rod is taken upon the bench. In the above example it is 1.637. As the bench is 30 feet above the assumed datum line, the height of the instrument (or line of collimation) above this datum line is 31.637 feet.

The reading is recorded against *Bench*, in the column of + *sights*, and the "height of instrument" is recorded in its proper column, in the same line.

By referring to the above diagram it will be readily seen, that to obtain the height of the different points 0, 1, 1^{60}, &c., above the datum line, it is only necessary to take the readings of the rod, at these stations, and subtract them from 31.637. Such readings, therefore, are appropriately termed *minus sights*, and are recorded in the 4th column. As these readings are taken only to the nearest tenth of a foot, they are taken much more rapidly than the bench readings. The subtractions by which the *surface heights* are found, may be worked in the field or not, as the surveyor chooses. The unit of measurement, in the column of distances, is usually the engineer's chain of 100 feet. Readings are taken at intermediate points (as at 160 feet in the above example) when there are abrupt changes in the inclination of the surface.

306. When it becomes necessary to change the position of the level, such measures must be taken as will insure the exact "height of instrument," in the new position.

To effect this, a carefully-selected hard point is found (not necessarily on the exact line of the survey, but as far forward as convenience and accuracy will permit), and a reading of the rod is taken upon it, to thousandths.

If likely to be used for a single occasion only, it is called a "*turning-point*," and marked T. P. in the distance column; otherwise it is called a *Bench*, and its location is described in the column of remarks.

A turning-point is taken between stations 3 and 4, in the above example. The reading of the rod, upon it, is 11.413. This is recorded in the — sight column, and the surface height of the point is at once found as before, and recorded in the column of "Heights."

The level is next carried forward to a new position, adjusted, and directed again upon the rod still held upon the turning-point. The reading is taken to thousandths. This, when *added* to the height of the turning-point, evidently gives the height of instrument in its new position. It is recorded, therefore, as a + sight. The survey is now continued by taking — sights at the various points along the line until it becomes again necessary to change the position of the level.

In the above example, the reading of the rod upon the turning-point, from the second position of the level, is 1.910. The height of the point upon which the rod stands is 20.224. The sum of these, or 22.134, is the "Height of Inst." for the second set of — sights. The successive subtractions of the readings from the Height of Instrument, give the surface heights as before.

The most extended section levels are but repetitions of this process.

305. The rules for taking and recording field-notes in section leveling are as follows:

I. *The "distances" recorded in the first column are the horizontal measurements, in chains, from the beginning of the survey to the points whose heights are to be determined. The heights are taken at each whole chain, and at such intermediate points as the irregularities of the surface require.*

II. *The first reading of the rod, after each setting of* *the level, is upon a bench or turning-point, and is a* "+ SIGHT;" *all other readings are* "— SIGHTS."

III. *The + sight, added to the height of the point upon which the reading was taken, gives the "Height of Instrument."*

IV. *The — sights taken, at any position of the level, subtracted from the "Height of Instrument" for that position, give the corresponding "Surface Heights."*

V. *All the +* SIGHT *readings, and the last — sight of each set, being upon benches or turning-points, are taken to thousandths of a foot. The remaining "— sights" are taken to tenths only.*

NOTE.—It will be observed that when the column of "surface heights" is complete, the second, third, and fourth columns of the field-notes are no longer needed. The first and fifth columns, which together contain the horizontal and vertical measurements for the line of work, afford all the data necessary for mapping the profile and determining the grade-line.

306. The location of the benches should be so described in the column of "remarks," that any particular bench may be found at any time, by referring to the field-notes. The importance of this is apparent when it is remembered that the process of construction destroys or removes the stakes along the line of the survey, and that the question of the completion of the work can be determined only by reference to the benches. It is obvious, also, that they should be established somewhat off the line of the survey. The distance apart, of regularly established benches, should be governed by the above-mentioned uses of them.

Any turning-point may be profitably made a bench (when it can be made permanent), by carefully recording, so as to admit [illegible]tification.

In order to eliminate the effects of curvature and refraction, "turning-points," whether used as benches or not, should be taken at equal distances from the instrument when practicable, or compensation should be secured by proportional distances, as in Art. **297**.

307. In conducting a section level through a rocky district, turning-points in abundance are found at hand, and cause no delay in their preparation, whereas a bench in the same section, requires marking and *locating*.

In leveling through flat and level sections of country, although the engineer can get "sights" for long distances, a proper regard for accuracy will induce him to limit the distance, between successive positions of the level, to about six hundred feet. Under such circumstances, each turning-point is made a bench.

308. The methods of establishing benches are various. In a rocky section, some conspicuous point is marked either by drilling or grooving the rock. In villages or cities, stone steps, or projecting courses of masonry to dwellings, curb-stones, and fence-posts afford good benches, and admit of easy identification.

In sections where trees abound, a notch is cut in the side of a trunk near the root, in such a manner as to leave a projecting point upon which the rod may be held vertically. A nail driven full length into the projection, gives it the necessary firmness for a bench.

In marshes or prairies, where there are neither rocks nor trees, the engineer is compelled to resort to long stakes, firmly driven into the ground to such a depth as to be undisturbed by the frost; no portion of the stakes being allowed to project above the surface. The top of each is trimmed to a kind of blunt point, into which a nail is driven its full length.

A re-survey of a route, to detect possible errors in leveling, is accomplished by taking the heights of the "benches" only, and is called a "check level."

Drawing the Profile.

309. When the "section level" of a line of work has been completed, the "profile" is next to be drawn. The method of doing this is very simple.

A horizontal line to represent the *datum* line is first drawn, and the distances from the first column of notes are laid off along it, to a convenient scale; this for ordinary working drawings is about two hundred feet to an inch.

The "surface heights" corresponding to these distances are next laid off at right angles to the datum line, and above it, but to a scale usually ten times as great as that employed for the horizontal distances; that is, an inch upon the vertical lines represents one-tenth as many feet as upon the datum line. A line joining the upper extremity of the verticals, is the profile.

By thus employing two different scales, the irregularities of the surface are made more apparent to the eye, and the subsequent adjustment of the "grade-line" is rendered much easier and more accurate.

310. Every earthwork of importance requires, in addition to the working profiles, a general map, in which the plan drawn from the transit survey is represented upon the same sheet as the profile.

The horizontal distances of both portions of the map being drawn to the same scale, and one being placed directly above the other, corresponding points in plan and profile are readily compared.

In published maps of this kind, representing extended works, and drawn for convenience to a very small scale, the vertical scale of the profile is frequently several hundred times as great as the horizontal.

Establishment of the Grade.

311. The determination of the height which the finished road or canal shall have above the datum line at different points, is called "Establishing the grade."

The position and inclination of grade-lines are influenced by a variety of circumstances:

1st. The character of the work. A street admits of an inclination of five, or even eight feet in a hundred, and requires about one foot for its drainage, while a rise of two feet in a hundred upon a railroad is exceedingly rare. A canal is, of course, level, the change of height being effected by abrupt transitions at the locks.

2d. The economy of construction. It is desirable to make the earth excavated, form the required embankments, or, in the language of the engineer, "to make the cuttings balance the fillings."

It is, however, sometimes more economical to throw away, or "make a spoil bank" of the earth of an excavation, than to transport it the required distance for the embankment. Embankments, for similar reasons, are often constructed of earth obtained outside of the road limits ("borrowing pits"); or, when such means are not available, are often made of timber framing (trestle-work).

3d. The natural obstacles, which render the construction difficult; such as rocky ledges, marshes, lakes, streams, and quicksands.

In any case, the engineer determines, by inspection of the maps, at what points the grade-line shall intersect the natural surface. Thus the inclination of the grade, and, consequently, its height above the datum line, for each "distance," are easily found.

Another column of notes is now made, recording these "Grade Heights;" each being placed against the corresponding *surface height*.

312. The following example, with its accompanying diagram, illustrates the method of establishing a grade and recording the notes. It will be observed that the profile, with its "distances" and "surface heights," are the same as in the preceding problem.

We will suppose it is required to establish, in the following profile, a grade-line whose inclination shall not exceed 3 in 100; the grade to begin at station 0, at the surface.

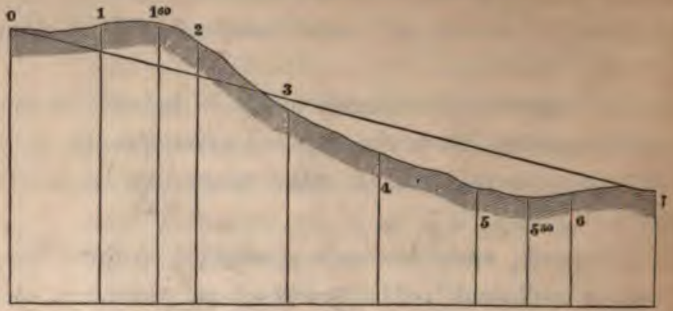


FIG. 143.

Dist.	+S.	H. of Ins.	−S.	H. of Sur.	H. of Gr.	Cut.	Fill.	Rem.
0				29.5	29.5			
1				29.8	26.8	3.0		
1^{60}				30.7	25.2	5.5		
2				28.2	24.1	4.1		0 at 2^{87}
3				20.8	21.4		0.6	
T.P.								
4				16.3	18.7		2.4	
5				13.1	16.0		2.9	
5^{50}				11.7	14.7		3.0	
6				12.3	13.3		1.0	
7				11.5				0 at 6^{53}

It is an easy matter to represent any required inclination of grade on the profile map; nothing more being necessary than to lay off the proper distances on two different verticals, and draw a line through the points of measurement. For instance: a grade of 3 in 100, running downward from station 0, would intersect the vertical at 6, eighteen feet lower, and the vertical at 7, twenty-one feet lower.

Moreover, by consulting the notes, we find that a grade-line from 0, whose height is 29.5 feet, ending at the surface at 7, whose height is 11.5 feet, descends 18 feet in 700, or 2.57 in 100.

Either of these lines would fulfil the required conditions. The first would, however, require in its construction a large excess of excavation over the embankment (as may be seen by drawing a faint line in the diagram). The second would give an excess of embankment.

It is best, generally, that the cutting should be slightly in excess, as nearly all kinds of earth shrink a little in the process of removal.

The cuttings and fillings of the profile may be balanced with tolerable accuracy, by stretching a thread across the profile so as to intersect at the 0 point, and then varying the inclination, until the areas cut off by the profile line on opposite sides of the thread appear equal.*

The column of Grade Heights must now be filled. It is easily and rapidly done. The height of Grade, at 0, is, by the conditions, 29.5. At station 1, it must be 2.7 lower, or 26.8; at 1.60, 4.3 lower, or 25.2; and at 2, 5.4 lower, or 24.1, &c.

The remaining columns of "cut" and "fill" contain simply the differences between corresponding "surface" and "grade heights." Where the surface is higher than the grade-line, the construction requires a "cutting;" when the established grade-line is higher than the surface, an embankment, or "filling," is necessary.

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* The advantage of a thread over a ruler lies in the fact, that while using the thread, the areas on both sides of it are seen at once.

In the present example, a line from 0, descending 2.7 to 100, seems to accomplish the desired purpose. The line being drawn, the "cut" and "fill" areas are measured, to determine if they are properly balanced.

The complete computation of the earthwork, by which the exact position of the grade-line is determined, is explained in a following section.

The notes in the final column, indicate the points where the grade-line intersects the natural surface. Such are called zero points.

The distances are of importance in the computation of the earthwork. The above notes literally signify that either cut or fill is 0, at 2.87, also at 6.52.

These distances are obtained with sufficient accuracy for ordinary purposes by a measurement of the profile map. When the cuttings and fillings are recorded in the proper columns, the notes belonging to the section-level are complete.*

NOTE.—It will be observed that the first set of notes on page 265, did not contain the columns for cut and fill.

The practice in keeping the notes differs with the work to be performed.

In extensive railway surveys, it is convenient to rule the pages of the note-book as in the first example; carrying out the field-notes to the extent of the surface heights, at least; then transfer to another book, the "distances," "surface heights," and "grade heights," ruling columns for "cut," "fill," and "remarks."

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* The following calculation may be employed in the more important cases. The triangles formed by the verticals (cut or fill), the grade-line, and the surface-line are similar, and give the following proportion:

The sum of the cut and fill,
: the cut,
:: the distance from cut to fill,
: distance from the cut to 0 point.

Fill may be substituted for cut in the second and fourth terms.

The application to the first zero point, in the above notes, is as follows:

4.1+0.6 : 4.1 :: 100 : required dist., or 87.

In the second case in the notes, the cut necessary to the calculation is wanting, but is easily supplied, by determining the height of grade in the usual way at station 7.

These transferred notes are recorded in ink, and reserved for use in mapping and computations.

313. Most road or canal surveys are made on several trial-lines before one is finally adopted. The profile of each line is carefully drawn, and the cost of construction approximately estimated.

When the route is finally selected, and the section levels satisfactorily completed, the exact width of the earthwork, both in excavations and embankments, is carefully staked out and the amount of material to be moved in the progress of construction, accurately measured.

The method of conducting this work is explained in a following section.

314. Before closing the subject of section leveling, we will consider the profile represented in the figure, and the set of field-notes appended, which are only partially completed, and which will afford some examples for practice.

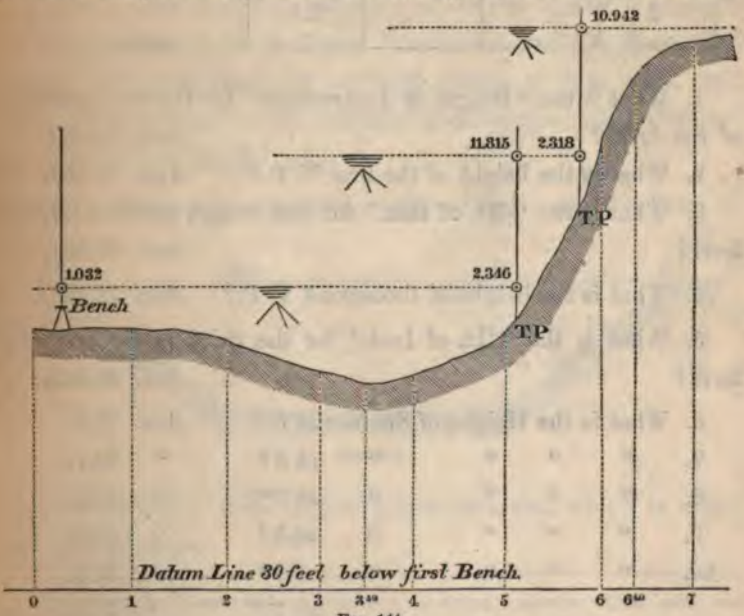

Fig. 144.

Dist.	+ S.	Ht. of Ins.	− S.	Surface Heights.	Remarks.
Bench.	1.032				
0			3.2		
1			3.8		
2			5.3		
3			8.9		
3^{50}			10.3		
4			9.0		
5			4.8		
T. P.	11.815		2.346		
T. P.	10.942		2.318		
6			9.7		
6^{40}			6.4		
7			2.1		

1. What is the "Height of Instrument" for the first position of the level? *Ans.* 31.032.

2. What is the height of the first T. P.? *Ans.* 28.686.

3. What is the "Ht. of Inst." for the second position of the level? *Ans.* 40.501.

4. What is the height of the second T. P.? *Ans.* 38.183.

5. What is the "Ht. of Inst." for the third position of th level? *Ans.* 49.125.

6. What is the Height of Surface at 0? *Ans.* 27.8.
7. " " " " at 3? " 22.1.
8. " " " " at 3^{50}? " 20.7.
9. " " " " at 5? " 26.2.
10. " " " " at 6? " 39.4.
at 7? " 47.0.

11. Write the "Surface Heights" for the distances 1, 2, and 6^{40}.

SECTION V.

CROSS-SECTION LEVELING.

315. All earthworks, whether excavation or embankment, unless held in position by retaining walls, require to be constructed with a sloping surface, the inclination of which depends upon the kind of earth.

If, in a railway-cutting, for instance, the banks which bound it be left too nearly vertical, when first constructed, the weathering influences, to which they are subjected, soon cause the material to slide down, until the whole slope gradually assumes a much lower inclination.

After a time, however, the tendency to roll or slide is checked by the friction of the particles themselves, and the slope thus formed will withstand the ordinary effects of sun, wind, and rain. The inclination thus assumed is called the "natural slope" of that kind of earth.*

316. Slopes are expressed mathematically by the ratio of their horizontal to their vertical dimensions, and which is called the *ratio of slope*.

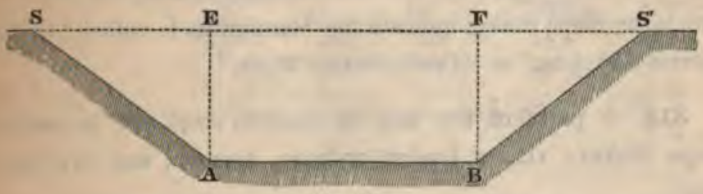

FIG. 145.

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* This slope is determined, experimentally, by drying a portion of the earth, and then pouring it from a slight elevation upon a level surface. The heap thus formed is a rather flat cone, whose sides stand at the lowest inclination they would be liable to assume under the action of atmospheric influences. The angle with the horizontal plane will be somewhere between 25° and 45°.

In the diagram, which represents a road-cutting, the ratio of *ES* to *AE*, or of *FS′* to *BF*, is the ratio of slope.

In practice, the slope at which earthworks are allowed to stand vary from 1 to 1, or 45° (as in very coarse material), to 2 to 1, or 26° 34′, in very fine sand.

A slope of 1½ to 1 (33° 41′) is found to be so far suitable for all ordinary excavations or embankments, that it is common, in the absence of an examination of the material, to adopt it as the ratio of slope throughout.

Setting Slope Stakes.

317. It is evident that the width of natural surface of ground, required in the construction of a road, will vary with the depth of excavation or embankment.

As often, therefore, as it is found necessary to determine the depth of the cutting or filling, in the section level, it is also necessary to mark the boundaries of the width of the work, on the natural surface. This is done by stakes called *Slope Stakes,* and the field-work necessary to determine their position, and to measure the section taken across the road of which the Slope Stakes indicate the boundaries, is called "Cross-Section Leveling," or "Cross-Section Work."

318. A party of five may be usefully employed in setting Slope Stakes; viz., a leveler, rodman, axeman, and two tapemen.

The rod, for cross-section work, is a ruder instrument than that employed in the section level. It should be at least fifteen feet long, with the feet and tenths plainly marked. It requires no target, the leveler himself reading the rod in the act of sighting.

The field-book is ruled as shown below:

Dist.	Left.	Centre cuttings.	Right.

The left-hand column contains the distances taken from the section-level notes. The third column is for the cut or fill, corresponding to the distance in the first column; these numbers also being taken from the notes of the section level.

A *filling*, it should be remarked here, is designated as a *minus cutting* in the field-notes.

The second and fourth columns are for the horizontal and vertical measurements of the cross-section.

319. The examples following will illustrate the method of measuring the section and recording the notes:

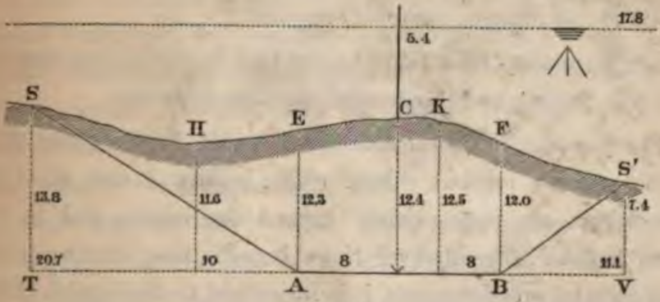

FIG. 146.

Let Figure 147 represent a section across a road excavation. *AB* being the bed of the road, and *SCS′* the line of the natural surface.

The road-bed is supposed to be 16 feet wide, the centre cutting 12.4 feet, and the ratio of slope $1\frac{1}{2}$ to 1.

The level being set up and adjusted in a convenient place, the rod is first held by the centre stake at *C*, and a reading taken.

In the present example, the reading is 5.4. The line AB forms a convenient datum line, and the height of the instrument above this line, is evidently $12.4+5.4=17.8$ ft.

This is noted down, for the moment, on a reversed page of the note-book, or on a spare slip of paper; neither the height of instrument or rod readings being matters of permanent record in cross-section work.

It is evident that if the rod be held at different points along the surface, and the readings subtracted from the "height of instrument," the remainders will be the heights of these points above the datum line AB. These heights are technically called *cuttings*, although in the case of ST and $S'V$, no actual excavation is proposed.

The reading at E is supposed to be 5.5. The cut is therefore $17.8-5.5=12.3$. The horizontal distance from the centre is 8 feet. For each cutting there will be a horizontal measurement, and these two must be recorded together.

The form adopted is that of a fraction in which the numerator is the cutting and the denominator the distance.

The record of this measurement would be, therefore, $\frac{12.3}{8}$, in the column marked "left." The points A and B, of the cross-section are appropriately termed the *angles*, and as the points E and F, directly over them, become new starting-points for horizontal measurements, it is important to distinguish them, in some way, in the notes.

(Right and left in the actual survey are determined by the direction in which the survey progresses, and in which the centre stakes are numbered.)

A common method is the one adopted in our notes—to substitute for the number which represents the half width of the road, the letter A.

The hind-chainman now takes his position at E, and the remaining distances to the left are measured from this point.

A change in the surface-line at *H* requires notice. The reading of the rod 6.2 indicates a cut of 11.6. This, with the distance from *E*, 10 feet, is duly recorded.

There being no other material change in the surface line beyond *H*, there remains to be determined on this side only the intersection *S*, of the surface and slope.

It is found by trial. When found, it is evident that the ratio of the distance to the "cut," must be the same as the ratio of slope. In the present example, the distance must be $1\frac{1}{2}$ times the cut.

Suppose a trial reading taken at 25 feet out, is 3.2. The height, or cut, is $(17.8-3.2) = 14.6$. $1\frac{1}{2}$ times this is only 21.9 feet. The distance tried, 25 feet, is too great.

Suppose a second trial at 22 feet out, with a rod reading of 3.8. The cut is 14. $1\frac{1}{2}$ times this is 21. Still too far out.

A third trial, at 21 feet out, and a reading of 4, gives a cut of 13.8 ft. This multiplied by $1\frac{1}{2}$ gives 20.7 feet. The measured distance is slightly too great, but in ordinary practice this approximation would be considered near enough. The record for the slope-stake *S* would therefore be $\frac{13.8}{20.7}$.*

In proceeding from the centre to the right, we find a point *K* between the centre and the angle, that requires attention.

The distance in such a case is taken from the centre instead of the angle. *CK* is 3 ft. and the rod reading 5.3 gives a cut of 12.5. The reading at the angle-stake *F* is 5.8, giving a cut of 12 feet.

If the surface-line from *F* were level, the distance *FS'* would be $12 \times 1\frac{1}{2} = 18$ feet; but as the ground descends, the distance is less.

---

* The readings and distances in this example have been made to correspond to a rise of one foot in five from *H* to *S*. The exact record for *S* is $\frac{13.7}{20.6}$.

A trial at 11 ft. with a reading of the rod of 10.4, indicates a cut of 7.4. This multiplied by $1\frac{1}{2}$ gives 11.1, which is very nearly right; $\frac{7.4}{11.1}$ is therefore the record for the location of S'.

The completed notes for this cross-section are as follows:

Dist.	Left.	Centre Cut.	Right.
——	$\frac{13.8}{20.7}$ $\frac{11.6}{10}$ $\frac{12.3}{A}$	12.4	$\frac{12.5}{3}$ $\frac{12}{A}$ $\frac{7.4}{11.1}$

320. We will now give a similar example, illustrating the method of staking out embankments:

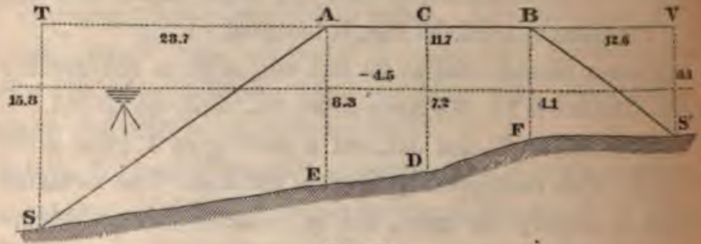

Fig. 147.

Dist.	Left.	Centre Cut.	Right.
——	$\frac{-15.8}{23.7}$ $\frac{-12.8}{A}$	−11.7	$\frac{-8.6}{A}$ $\frac{-8.4}{12.6}$

The filling at the centre is assumed to be 11.7 ft., which appears in the column of "centre cut," with its appropriate sign.

The reading of the rod, at the centre, as shown by the diagram, is 7.2.

The sum of the reading and the centre cut (7.2 — 11.7) is —4.5, which is the "height of instrument" referred to the line *AB*.

The readings at all other points along the line *SS′* must be subtracted from this "height of instrument," as in the preceding example. The several remainders are the corresponding "cuttings."

The reading at angle stake *E*, 8.3, subtracted from —4.5, gives —12.8, for the cut.

For the slope stake *S*, we will suppose a trial distance of 20 feet from *E*, and a rod reading at the trial point of 10.8 feet. The cut is therefore — 15.3; this multiplied by 1½ gives 22.95.* The trial distance therefore, 20 feet, is not enough.

A trial of 24 feet out, we will suppose to give a rod reading of 11.3 ft., which corresponds to a cut of —15.8 ft. The ratio applied to this, gives for the proper corresponding distance out, 23.7 ft., which is nearly correct. The distance at which the trial was made is slightly too great. It is evident that if the slope stake be set at the calculated distance, 23.7 ft., the record of $\frac{-15.8}{23.7}$ may be made without involving an error of more than a tenth of a foot, in either cut or distance.

On the right, the reading at the angle stake *F* is 4.1. The cut, therefore, is —8.6 feet.

As the surface rises but little from *F* to *S′* the trial distance for the slope stake is taken at 12 feet; (it should be 12.9 ft., if the surface were level); the reading is supposed to be 3.9 feet. This gives the cut —8.4, which should correspond to a distance out of 12.6 feet. It is evident, that considering the rise in the surface and the rod readings at *F* and *S′*, the rod reading at *S′*

---

* The sign is disregarded in the product. It may be well to notice, however, that the ratio of slope in embankments is considered to be 1½ to −1.

would not vary a tenth if moved from 12 feet to 12.6. The record, therefore, for S' is $\frac{-8.4}{12.6}$.

NOTE.—It is not necessary to take rod readings at the angle stakes. If desired, these readings can be omitted and rod readings taken at the centre stake, and right and left from it at each change of inclination of surface. It is often convenient, however, particularly for beginners, to take the angle stake readings, and hence in the rule these readings are assumed to be taken.

321. The rules for conducting and recording cross-section work, whether for excavation or embankment, are as follows:

I. *Prepare the field-book by ruling columns for Distances and Centre Cuttings, leaving wider spaces on each side of the latter column for the record of the various measurements to the left and right of the centre stake. Transfer from the section-level notes the distance and corresponding cut or fill, for each stake of that survey. Filling in the cross-section notes is designated as* minus *cutting.*

II. *Having set the level in convenient proximity to a proposed cross-section, take a reading of the rod at the centre-stake. Add this reading to the centre cutting, (regarding the sign of the latter), to obtain the "height of instrument."*

III. *Lay off half the width of the road-bed each side of the centre, and mark the distances, temporarily, with stakes. These are the angle stakes.*

IV. *Proceed to take rod readings at the angle stakes, and beyond them outward (on a line at right angles to the direction of the line of the road), at each change of inclination of the surface. Subtract each reading from* *the height of instrument; the remainder is the cutting, or vertical distance of the point measured, from the proposed road-bed.*

V. *Record each cutting, together with its horizontal distance from the nearest angle stake, in the form of a fraction expressing the ratio of the distance to the cutting. Each fraction being recorded in its proper column either "right" or "left" of the centre. Points between the centre and angle stake, are located by measurements from the centre.*

VI. *To find the position of the slope stake: Measure off a trial distance from the angle stake, and determine the cut as before. Multiply the cut by the ratio of height to base of the proposed slope. If the trial distance be greater than this product, the assumed point is too far out, and vice versa. Repeat the trial until the ratio of the distance to the cut expresses the ratio of slope.*

322. The cutting at the angle stake is, in cases of a tolerably uniform surface, a good guide to the distance to the slope stake. Thus, when the angle cutting of an excavation is 16 feet and the ratio of slope 1½ to 1, the distance out, for a level surface, would be 24 feet; but if the ground in that distance rise 2 feet (and which in practice may be determined pretty correctly by the eye), then the horizontal distance must be increased by something more than 1½ times 2 feet.

When the surface descends, the estimated distance out, for a level surface, should in like manner be diminished. In embankments the conditions are reversed; the steeper the rise, the shorter the distance out.

323. The following examples will serve to elucidate the subject still further:

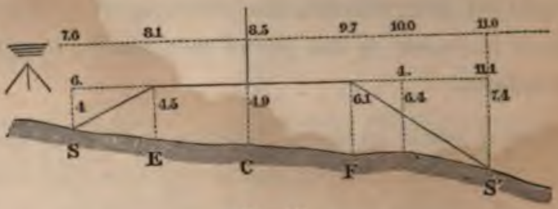

Fig. 148.

Dist.	Left.		Centre Cut.	Right.		
——	$\frac{-4.}{6.}$	$\frac{-4.5}{A}$	-4.9	$\frac{-6.1}{A}$	$\frac{-6.4}{4}$	$\frac{-7.4}{11.1}$

Figure 148 represents an embankment cross-section, in which, by reason of the small depth of filling, the height of instrument is a positive quantity.

The centre cut is −4.9; reading of the rod at the centre, 8.5; the sum of these, or "height of instrument," is 3.6. The remaining rod readings are given on the line through the instrument.

324. In the example of the following diagram (Fig. 149), the cross-section is partly in excavation and partly in embankment. The ratio of slope is 2 to 1. The centre cut is 2.4. The centre reading is 7.9; height of instrument, 10.3.

The reading at *H*, is 6.3; at *E*, 6.1; at *S*, 5.4. The point, *K*, is easily found in practice, it being that point on the surface line where the reading of the rod exactly equals the height of instrument. The reading at *F* is 13.2; and at *S′*, 15.8.

From these readings the cuttings may be found, and the [illegible] below.

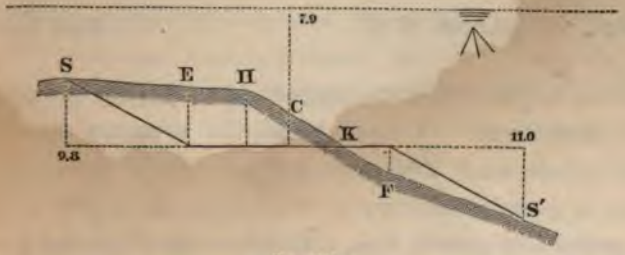

FIG. 149.

Dist.	Left.			Centre Cut.	Right.		
—	$\frac{4.9}{9.8}$	$\frac{4.2}{A}$	$\frac{4.0}{3.8}$	2.4	$\frac{0}{.4}$	$\frac{-2.9}{A}$	$\frac{-5.5}{11}$

325. In the following example, there is a regular rise in the surface-line of one foot in eight. The ratio of slope in the excavation is to be $1\frac{1}{2}$ to 1; height of instrument, 14.2.

In seeking for the position of the slope-stake *S′*, a distance out of 13 feet is tried; the reading of the rod at the trial point is 4.8.

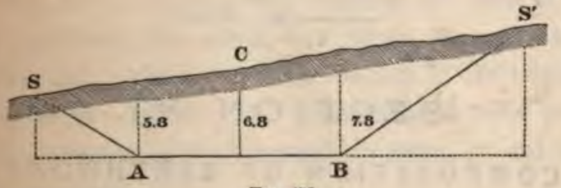

FIG. 150.

How does this point compare with the true position of *S′*?

Ans. Not far enough out.

What is the result of a trial at 16 feet out and a reading of 4.4?

Ans. Too far out.

What is the true cut and distance at *S′*? *Ans.* $\frac{9.6}{14.4}$.

Find the position of *S*. *Ans.* $\frac{4.9}{7.3}+$.

NOTE 1.—It sometimes happens in very hilly sections, that it is impracticable to sight to all the necessary points of a single cross-section from one position of the level. In such a case, it is only necessary to work from the centre as far as the surface will permit, then establish a turning-point, precisely as in section leveling; change the position of the level so as to proceed with the work, and determine the new height of instrument, from which the readings are to be subtracted as before.

NOTE 2.—The degree of accuracy desirable to be attained in setting the slope stake, varies with the kind of earth to be "staked out," so that no exact rule can be laid down.

A principle, in quite general use, permits the stake to be set when the calculated distance varies from the trial distance by less than a foot.

The limit of error should never be greater than this, but in rock and the harder kinds of earthwork, it should be made much less.

SECTION VI.

COMPUTATION OF EARTHWORK.

326. Before the work of construction of a railroad or canal commences, the calculation of the earthwork must be completed.

The cross-section levels afford the necessary data. These surveys have divided the proposed work into blocks of 100 feet, or less, in length, and which are appropriately termed prismoids.

Different methods are employed for estimating their cubic contents. The most accurate, though the most laborious, is the prismoidal formula (Leg., Mensuration, page 129),

$$\text{vol.} = \frac{l}{6}(B + B' + 4M).$$

B and B' representing the areas of the end sections of the prismoid, M the area of a section midway between them, and l the entire length of the solid.

The principal difficulty in applying this formula lies in finding the dimensions of the middle section.

327. We will show the application of the formula by an example of road excavation.

To simplify the problem, we will suppose such a degree of regularity in the ground surface that the angle cuttings may be omitted.

The length is supposed to be 100 feet. The other dimensions are given in the diagram.

The areas of the end sections are easily found. It is only necessary, in each case, to add together the areas of the trapezoids composing the whole end figure, as represented in the diagram, and subtract therefrom the sum of the triangles which lie outside the section. The dimensions of these triangles are always expressed in the cross-section notes, by the records for the slope stakes.

The area of B is thus found to be 104.8 sq. feet, and of B', 116 sq. feet.

Now, if a section of this prismoid be taken midway between the two ends, each of its several dimensions must be an arithmetical mean of the corresponding measurements of the end sections. Thus, the centre cutting is found to be 5 ft.; the distance from the angle to slope stake, on the left, 9.9 ft., $\left(\frac{10.8+9}{2}\right)$; the cutting on the extreme left is 6.6 ft. $\left(\frac{7.2+6}{2}\right)$, &c.

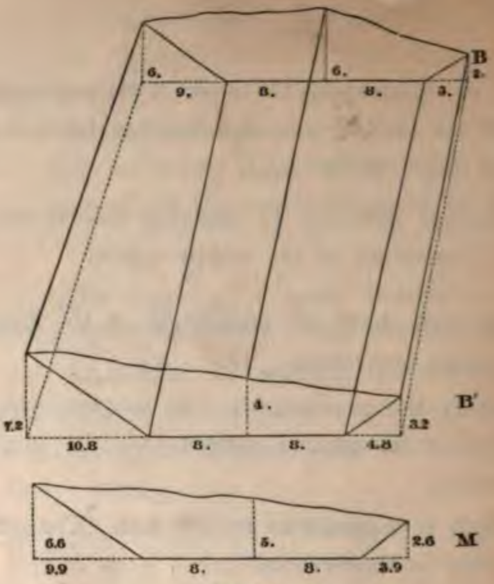

FIG. 151.

The area of M is 111.3 sq. ft.

$$\text{Vol. of the prismoid} = \frac{1}{6} \times 100\ (104.8 + 116 + 445.2),$$
$$= 11100 \text{ cubic feet.}$$

328. In applying the prismoidal formula to an example in which one end section has more given dimensions than the other, the calculator is frequently in doubt how he shall average these dimensions to obtain the middle section. As a rule, each cutting of the most irregular section should be averaged with the cutting nearest opposite to it in the other section.

We will illustrate this by an example; representing the sections by the field-notes only.

Dist.	Left.	Centre Cut.	Right.
2	$\frac{17.2}{25.8}$ $\frac{16.8}{A}$ $\frac{16}{2}$	15.8	$\frac{13}{A}$ $\frac{10}{8}$ $\frac{8.4}{12.6}$
2.60	$\frac{11.6}{17.4}$ $\frac{11.2}{A}$	10.4	$\frac{10}{A}$ $\frac{8}{12}$

The half-width of the road, for which *A* is given in the notes, is to be considered as 8 feet. The length of the prismoid is expressed by the difference of the given distances, or 60 feet.

The dimensions of the middle section are found as follows:

The centre cut is half the sum of the given similar dimensions, $\frac{15.8+10.4}{2} = 13.1$ feet.

On the right, the average of the angle cuttings gives $\frac{11.5}{A}$; for the next measurement, both cut and distance must be averaged; it is,

$$\begin{aligned} \tfrac{1}{2}\times(10+8) &= 9 \\ \tfrac{1}{2}\times(8+12) &= 10 \end{aligned} \quad \text{or} \quad \frac{9}{10}.$$

The last term in the upper section must be averaged with the last in the lower, thus:

$$\begin{aligned} \tfrac{1}{2}\times(\ 8+\ 8.4) &= \ 8.2 \\ \tfrac{1}{2}\times(12+12.6) &= 12.3 \end{aligned} \quad \text{or} \quad \frac{8.2}{12.3}.$$

On the left, the measurement $\frac{16}{2}$ of the upper section, must be averaged with the centre cutting of the lower, being nearest opposite to that point. We have,

$$\begin{aligned} \tfrac{1}{2}\times(16+10.4) &= 13.2 \\ \tfrac{1}{2}\times(\ 2+\ 0\ ) &= \ 1 \end{aligned} \quad \text{or} \quad \frac{13.2}{1}.$$

At the angle, in like manner, we have $\frac{14}{A}$; and finally at the slope stake $\frac{14.4}{21.6}$. The complete dimensions being

$$\frac{14.4}{21.6}\quad\frac{14}{A}\quad\frac{13.2}{1}\;\Big|\;13.1\;\Big|\;\frac{11.5}{A}\quad\frac{9}{10}\quad\frac{8.2}{12.3}.$$

The area of the upper section, after subtracting the triangles, as before, is 543.47 sq. feet.

The area of the lower end section is 325.44.

The middle section contains 429.8 sq. feet.

The volume of the prismoid is

$$\tfrac{1}{6}\times 60\,(543.47+325.44+4\times 429.8)$$
$$= 25881.1 \text{ cubic feet, or } 958.56 \text{ cubic yards.}$$

329. The following method* of computing the contents of consecutive volumes between regular cross-sections of excavation and embankment, contained by uniform slopes, will be found of service.

The accompanying diagram represents the cross-section of a railroad cut, b being half the width of road-bed, c centre-height,

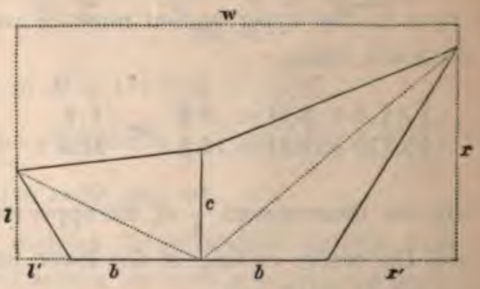

FIG. 152.

r elevation of right slope-stake above grade, r' its horizontal distance from nearest side of road-bed, l elevation of left slope-stake, l' its horizontal distance from nearest side of road-bed, and

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* "Formulæ for Railroad Earthwork," by J. Woodbridge Davis, C. E., Ph. D.

w the entire top-width or horizontal distance between slope-stakes. The area of this section is evidently

$$\tfrac{1}{2}rb + \tfrac{1}{2}lb + \tfrac{1}{2}c\,(r' + b) + \tfrac{1}{2}c\,(l' + b).$$

Let S denote the ratio of slope; then $S = \frac{r}{r'} = \frac{l}{l'}$, and $r = Sr'$, $l = Sl'$. Substituting and reducing,

$$\textit{Area Section} = \tfrac{1}{2}Sb\,(r' + l') + \tfrac{1}{2}c\,(r' + l' + 2b).$$

Adding and subtracting Sb^2 does not change its value;

$$\therefore \quad \textit{Area Section} = \tfrac{1}{2}Sb\,(r' + l' + 2b) - Sb^2 + \tfrac{1}{2}c\,(r' + l' + 2b),$$

or

$$\textit{Area Section} = \tfrac{1}{2}w\,(c + Sb) - Sb^2.$$

Supposing w', c' to represent width and centre at next station, the area of its cross-section may be expressed by a formula similar to the above; half the sum of these, multiplied by the distance, D, between, and divided by 27, gives a near approximate of the volume in cubic yards;

$$\textit{Vol.} = [wc + w'c' + Sb\,(w + w') - 4Sb^2]\,\tfrac{D}{108}.$$

Add two consecutive volumes of equal length by means of the general formula, w'', c', representing the width and centre of third cross-section:

$$\textit{Vol.} = [wc + 2w'c' + w''c'' + Sb\,(w + 2w' + w'') - 8Sb^2]\,\tfrac{D}{108}.$$

By continual addition we may get a formula for the sum of any number of consecutive volumes; but, letting n denote the number of volumes, we may at once indite a general formula for the calculation of any number of volumes consecutive. Thus we have

$$\textit{Vol.} = \left\{ \begin{array}{c} wc + 2w'c' + \&c. + 2w_nc_n + w_{n+1}c_{n+1} \\ + Sb(w + 2w' + \&c. + 2w_n + w_{n+1}) - 4Sb^2n \end{array} \right\} \frac{D}{108}.$$

Divide and multiply by 2 to convert the formula into more convenient shape, call $w'c'$, $w''c''$, &c., mid-products, wc and $w_{n+1}c_{n+1}$ end-products, and we have

$$Vol. = \left\{ \begin{array}{c} mid\text{-}products + \tfrac{1}{2}\, end\text{-}products \\ + Sb\,(mid\text{-}widths + \tfrac{1}{2}\, end\text{-}widths) \\ - 2Sb^2 \times no.\ of\ vols. \end{array} \right\} \frac{D}{54}.$$

Let us illustrate this formula by applying it to the following extract from a field-book, containing columns of stations, centre cuts, left and right heights and distances of slope-stakes, the road-bed being 18 feet, slope 1 to 1, distance apart of stations, 100 feet:

Station.	Left.	Centre.	Right.
1	$\frac{1.1}{10.1}$	3.0	$\frac{4.0}{13.0}$
2	$\frac{3.6}{12.6}$	5.1	$\frac{6.2}{15.2}$
3	$\frac{6.0}{15.0}$	6.4	$\frac{7.5}{16.5}$
4	$\frac{8.1}{17.1}$	7.2	$\frac{8.0}{17.0}$
5	$\frac{10.5}{19.5}$	9.0	$\frac{9.5}{18.5}$
6	$\frac{7.3}{16.3}$	6.7	$\frac{6.4}{15.4}$

OPERATION.

Stations.	Widths.		Centre.		Products.
1	11.55	×	3.0	=	34.65
2	27.8	×	5.1	=	141.78
3	31.5	×	6.4	=	201.60
4	34.1	×	7.2	=	245.52
5	38.0	×	9.0	=	342.00
6	15.85	×	6.7	=	106.195
9 or $Sb \times$	158.80				1071.745
					1429.2
					−810.
				9)	169094.5
				6)	18788.3
					3131.38 cu. yds.

330. The foregoing method of calculating earthwork is approximate. To find the true contents we use a formula of correction, which is obtained in the following manner. Let

$$\tfrac{1}{2}w\,(c+Sb)-Sb^2,\ \tfrac{1}{2}w'\,(c+Sb)-Sb^2\,.$$

be the end areas of a volume of earthwork. Then $\frac{1}{2}(w+w')$, $\frac{1}{2}(c+c')$ are evidently the width and centre of mid-section, and its area is

$$\tfrac{1}{4}\,(w+w')\left(\frac{c+c'}{2}+Sb\right)-Sb^2.$$

Multiply this by 4, add thereto the end areas, multiply all by $\frac{1}{6}$ D, and divide by 27, to obtain in cu. yds.

$$\textit{True vol.}=\left(\begin{matrix}2\,(wc+w'c')+(wc'+w'c)\\ +3Sb\,(w+w')-12Sb^2\end{matrix}\right)\frac{D}{324}.$$

This formula would prove very unwieldly to carry through the calculations for series of volumes, especially in the consideration of intermediate stations. The same results may be obtained in a simpler manner by using the difference between true and approximate contents as a correction. Subtracting the approximate volume,

$$[wc+w'c'+Sb\,(w+w')-4Sb^2]\,\tfrac{D}{108},$$

from the true, we have, after reduction,

$$\frac{(w-w')\,(c'-c)\,D}{324},$$

for the error or correction.

Pris.	Cor.
—	987
—	481
—	208
—	702
—	1449

12) 3827

9) 319

3) 35.4

—11.81 Cor.

3131.38 Approx. con'ts.

3119.57 True con'ts.

We see by the formula that to correct a volume, the difference of widths, found by a subtraction in one direction, must be multiplied by the difference of centres resulting from a subtraction in the opposite direction, this product multiplied by the length of volume and divided by 324. Applying this rule to the second volume of example, we have *width* at station 2 [27.8]—*width* at station 3 [31.5] = —3.7; *centre* station 3 [6.4]—*centre* station 2 [5.1] = 1.3. —3.7 × +1.3 × 100 = —481. Set this in an extra column. Treat each volume in like manner, remembering that the first and last numbers in column of widths are half-widths. We here represent the column of corrections. The sum, —3827, divided by 324, is —11.81 cu. yds. This added to the approximate result yields for the true answer 3119.57 cu. yds.

It may happen, in practice, that some of the volumes involved need no correction whatever, which fact will be apparent from the formula by inspection and without actual labor.

BOOK VIII.

TOPOGRAPHICAL SURVEYING.

331. Besides the surveys that are made to determine the area of land and the relative positions of objects, it is frequently necessary to make minute and careful examinations for the purpose of ascertaining the form and accidents of the ground, and to make such a plan as will distinguish the swelling hill from the sunken valley, and the course of the rivulet from the unbroken plain.

This branch of surveying is called Topography. In surveys made with a view to the location of extensive works, the determination of the slopes and irregularities of the ground is of the first importance; indeed, the examinations would otherwise be useless.

332. The manner of ascertaining these irregularities is, to suppose the surface of the ground to be intersected by a system of horizontal planes at equal distances from each other; the curves determined by these secant planes, being lines of the surface, will indicate its form at the places of section, and, as the planes are nearer or more distant from each other, the form of the surface will be, more or less, accurately ascertained.

If such a system of curves be determined, and then projected or let fall on a horizontal plane, it is obvious that the curves on such plane will be nearer together or farther apart, as the ascent of the hill is steep or gentle.

of the distances *ae, bf, ai, bl,* &c., be measured with the chain, and there will then be known the three sides of the triangles *Aae, Abf, Aai, Abl,* &c.

Let, now, the difference of level of all the points marked in each of the lines *AB, AD, AC,* be determined, being careful to hold the rod upon a point near each stake which represents the general surface, and not at the bottom of a hole nor upon the top of a mound, a precaution to be observed in every leveling operation.

Let now the heights of all the points marked on each of the lines *AB, AD,* and *AC,* be found with reference to the datum plane, which, near the coast, may be the plane of mean low water, or a plane assumed so that it will lie below the lowest point to be delineated.

In the present example, of a single slope only, the results of the measurements and leveling are:

Line *AB*.

Distances.	Heights above datum plane.
$Aa = 40$ feet.	$A = 64$ feet.
$ab = 50$ "	$a = 52$ "
$bc = 30$ "	$b = 44$ "
$cd = 46$ "	$c = 35$ "
	$d = 24$ "

Line *AC*.

Distances.	Heights above datum plane.
$Ae = 28$ feet.	$A = 64$ feet.
$ef = 45$ "	$e = 53$ "
$fg = 55$ "	$f = 44$ "
$gh = 49$ "	$g = 32$ "
	$h = 18$ "

Line AD.

Distances.	Heights above datum plane.
$Ai = 25$ feet.	$A = 64$ feet.
$il = 55$ "	$i = 55$ "
$lm = 38$ "	$l = 42$ "
$mn = 48$ "	$m = 35$ "
	$n = 21$ "

Angle $CAB = 25°$, Angle $DAB = 30°$.

These data are sufficient, not only to find the intersections of horizontal planes with the surface of the hill, but also for delineating such curves of section on paper.

Plot of Work.

335. Having drawn, on the paper, the line AB, lay off the angle $BAC = 25°$, and the angle $BAD = 30°$. Then, from a convenient scale of equal parts, lay off the distances Aa, ab, bc, cd, Ae, ef, fg, gh, Ai, il, lm, and mn.

Let the horizontal planes be passed at distances of 8 feet apart, in which case the point A, in the example given, will lie in the eighth contour plane, counting from the datum plane. Since A is the highest point of the hill, and the difference of level of the points A and a, is 12 feet, the first plane, reckoned downwards, will intersect the line traced on the ground from A to B, between A and a. Regarding the descent as uniform, which we may do for small distances, without sensible error, we have this proportion: as the difference of level of the points A and a, is to the horizontal distance Aa, so is 8 feet, to the horizontal distance from A to where the first horizontal plane will cut the line from A to B. This distance being thus found, and laid off from A to o, gives o, a point of the curve in which the seventh plane intersects the ground. The points at which it cuts the line from A to C, and the line from

A to *D*, are determined similarly, and three points in the seventh curve are thus found.

The graphic operations are greatly facilitated by the aid of a sectoral scale of equal parts, of which Fig. 154 is a representation.

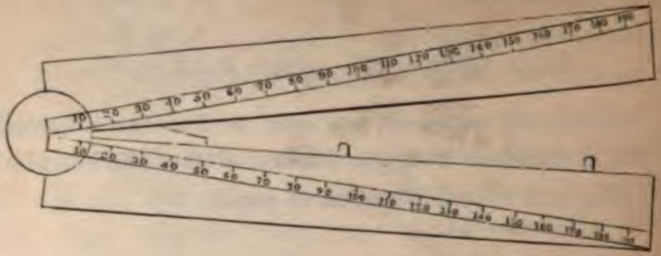

FIG. 154.

It consists of two arms, or sides, which open by turning round a joint at their common extremity.

On each arm of the sector, there is a diagonal line that passes through the point about which the arms turn: these diagonal lines are divided into equal parts.

The advantage of the sectoral scale of equal parts, is this:

Let it be proposed to draw a line upon paper, on such a scale that any number of parts of the line, 40 for example, shall be represented by one inch on the paper, or by any part of an inch. Take the inch, or part of the inch, from the scale of inches, on the sector; then, placing one foot of the dividers at 40, on one arm of the sector, open the sector until the other foot reaches to the corresponding number on the other arm; then, lay the sector on the table without varying the angle.

Now, if we regard the lines on the sector as the two sides of [illegible], of which the line 40, measured across, is the base, it is plain, that if any other line be likewise measured across the angle of the sector, the bases of the triangles, so formed, will be proportional to their sides. Therefore, if we extend the dividers from 50 to 50, this distance will represent a line of 50, to the given scale; and similarly for other lines.

In the example before us (Fig. 153), let it be borne in mind, that the descent from *A* to *a*, is 12 feet, and that it is required, upon the supposition of the descent being uniform, to find that part of the distance corresponding to a descent of 8 feet. Take the distance from *A* to *a*, in the dividers, and open the arms of the sector until the dividers will reach from 12 on the line of equal parts, on one side, to 12 on the line of equal parts on the other. Then, without changing the angle, extend the dividers from 8 on one side to 8 on the other; this will give the proportional distance to be laid off from *A* to *o*. Or, if the dividers be extended from 4 to 4, the proportional distance may be laid off from *a* to *o*.

If the distances to be taken from the sector fall too near the joint, let multiples of them be used.

336. The sixth plane is to pass 8 feet below the first, that is, 16 feet below *A*, or 4 feet below *a*, *a* being 12 feet below *A*. Take the distance *ab*, in the dividers, and extend the sector, so that the dividers will reach from 8 to (the descent from *a* to *b* being 8 feet) 8, or from 80 to 80; then, the distance from 4 to 4, or from 40 to 40, being laid off from *a* to *p*, gives *p*, a point of the sixth curve.

The difference of level between *a* and *b* being 8 feet, and the difference of level between *a* and *p* being 4 feet, the difference of level between *p* and *b* must also be 4 feet; hence, the fifth plane will pass 4 feet below *b*, and *q*, determined as above, is a point of the fifth curve, and so on. After having determined the points in which each contour line cuts the lines diverging from *A*, let the contour lines be drawn through them, so as to indicate the surface of the hill. The numbers (64), (56), &c., show the vertical distances of the respective planes above the plane of reference.

337. Having drawn the horizontal curves, the next thing to be done is so to shade the drawing that it may represent accurately the surface of the ground. This is done by drawing a system of small broken lines, as in the figure, perpendicular in direction to the horizontal curves already described. In all topographical representations of undulating ground, the lines of shading are drawn perpendicular to the horizontal curves, to indicate the direction of the flow of water down the declivity.

A profile along either of the diverging lines may be plotted by the rules already given. Fig. 155 shows the profile along the line *AB*.

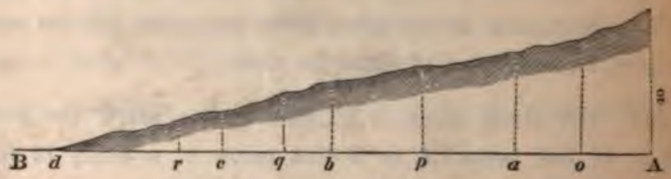

FIG. 155

EXAMPLE SECOND.

338. The following example will illustrate the methods employed in making a topographical survey, where great accuracy is required.

By means of a transit or level, range a line of stakes *A*, *B*, *C*, *D*, *E*, &c., Fig. 156, along one side or through the middle of the ground to be surveyed, at equal and convenient distances from each other, say 100 feet apart. Mark, with a piece of red chalk, on each stake in this row, one of the letters of the alphabet,

A, B, C, D, E, &c., in their order. At A, range a line of stakes, perpendicular to AE, planting the stakes at intervals of 100 feet; and mark them with the letters A_0, A_1, A_2, &c., which are read A zero, A one, A two, &c.

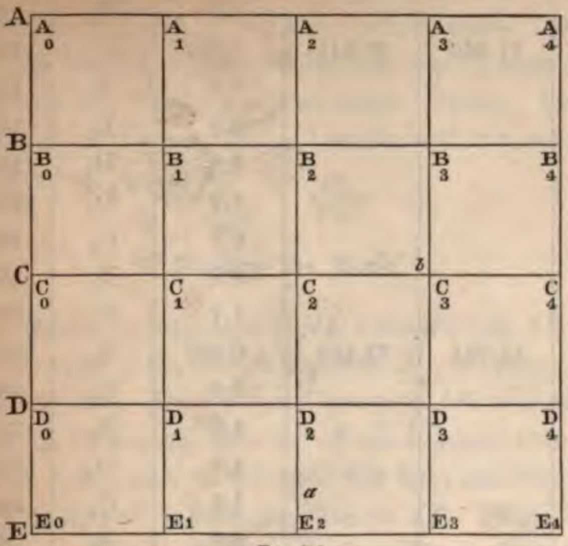

FIG. 156.

At B, range a line of stakes also perpendicular to AE, and at distances of 100 feet from each other, and designate them B_0, B_1, B_2, &c. Do the same at C, D, E, &c., until all the stakes are placed, dividing the area to be surveyed, into squares of 100 feet on a side. The letters and figures should be plainly marked on a smooth face of each stake, for facility of reference. If this system of notation be followed, the stakes may be recorded without danger of confusion.

339. The following is the form of a field-book, used in topographical leveling:

Field Notes.

Benches.	+ Sights.	Height Inst.	− Sights.	Stations.	Heights.
Bench	4.136	12.142	12.1	E_2	0.0
			1.9	D_2	10.2
C_3	11.906	22.441	1.607	C_3	10.535
			6.0	E_1	16.4
			6.9	E_3	15.5
			6.8	D_3	15.6
			1.9	D_1	20.5
			3.7	C_2	18.7
			6.8	B_4	15.6
			1.7	C_4	20.7
B_3	11.914	33.448	0.907	B_3	21.534
			8.0	E_0	25.4
			4.0	B_2	29.4
			4.1	D_0	29.3
			1.9	C_1	31.5
			5.0	A_3	28.4
			9.9	A_4	23.5
			1.7	D_4	31.7
			1.1	E_4	32.3
			0.1	A_2	33.3
C_0	11.813	45.225	0.036	C_0	33.412
			4.8	B_1	40.4
			2.6	B_0	42.6
A_1	8.925	52.669	1.481	A_1	43.744
			3.2	A_0	49.5

340. In the example taken for illustration the point E_2 is the lowest point.

Set up the level and take a reading upon a bench, which ha been determined to be 8.006 feet above some plane of reference, the sea level for instance. Suppose the reading to be 4.136, which is entered in the "+ Sight" column. The "Height of Instrument" will therefore be 12.142, as entered in the proper column. Next take readings upon E_2, D_2, and C_3, reading C_3 to thousandths as it will be used as a "turning point" (Art. **304**). Remove the level to a new position and read C_3 again, 11.906, which gives a new "Height of Instrument" 22.441. From this position read as many stations as possible, and then use B_3 as a "turning point," and so on.

Plotting the Work.

341. Draw, on a piece of paper, a straight line *AE*. From a scale of equal parts, set off distances *AB*, *BC*, &c., each to represent 100 feet. Erect perpendiculars to *AE*, at each of the points *A*, *B*, *C*, &c., and then set off the distances from *A* to 1, from 1 to 2, &c., each to represent 100 feet; and through the points 1, 2, 3, and 4, draw parallels to *AE*. These, by their intersections with the lines drawn through *A*, *B*, *C*, &c., will determine the position of the stakes A_0, A_2, &c.; and write in red ink on the plot, the height above the plane of reference of each stake, taken from the column of total differences in the field-book. Let us suppose that the horizontal planes are to be taken at distances of 6 feet. We may find the points in which the contour lines intersect the sides of the rectangles, as in Example First. A very convenient scale for finding the points in which the contour lines cut the sides of the rectangles may be constructed thus: Upon any line as *AB*, Fig. 157, erect equidistant perpendiculars as at 0, 1, 2, &c. Parallel to *AB* draw lines, alternately heavy and light, as at 1, 2, 3, &c. Suppose we wish to find where the 12-foot plane cuts the side of a rectangle, C_3C_4 for example. The height of C_3 is 10.5, and of C_4 it is 20.7, from which data we find the rise from C_3 to C_4 to be 10.2. The rise from C_3 to the 12-foot plane is 1.5.

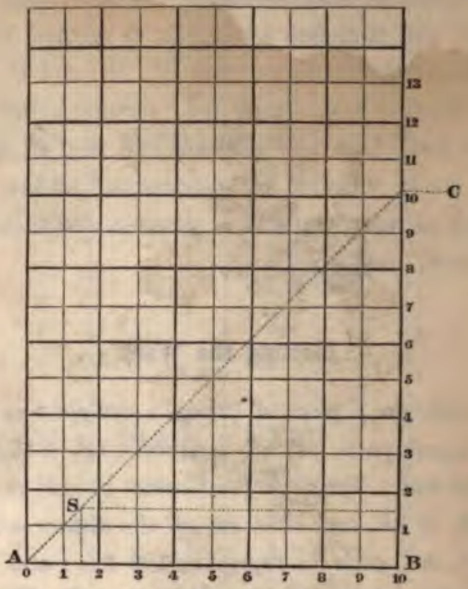

FIG. 157.

Now fasten a fine thread at A on the scale, and stretch it to cut 10.2 on the vertical scale, as AC in Fig. 157. Look along the horizontal line 1.5, as dotted, and its intersection with AC will be at S, distant 16 ft. on the horizontal scale from A, or C_3. The tenths on the vertical and horizontal scales may be estimated by the eye with sufficient accuracy. Engineer's Section Paper may be advantageously used for the above purpose.

342. If only a rough plot is needed, the Surveyor may take the plot thus commenced, into the field, and by the eye trace the contour lines on the map. If we note where the lines of the rectangles cut fences, roads, streams, &c., we can, by joining the *points*, obtain a plot of the ground.

The contour lines may be traced on the ground as follows: Set up the instrument and read a staff placed upon a bench, and determine the height of instrument above the datum plane. Suppose it to be 11.432. If we wish to mark out the contour line six feet above the datum plane, we set the target of the leveling rod at 11.432 − 6 = 5.432, and direct the rodman, by signals, up or down the hill, till the horizontal wire of the telescope coincides with the horizontal line of the vane. The foot of the staff is then 6 feet above the datum plane. Let a stake, marked 6, be driven here, and direct the rodman around the hill, until a second position shall be found, when the horizontal wire of the telescope will cut the vane, and drive there another stake, marked 6; and so on, until a sufficient number of stakes have been driven to determine the curve (6). Then, let the line of stakes, marked 6, be surveyed with the compass and chain, and plotted. Other contour lines may be found in a similar manner.

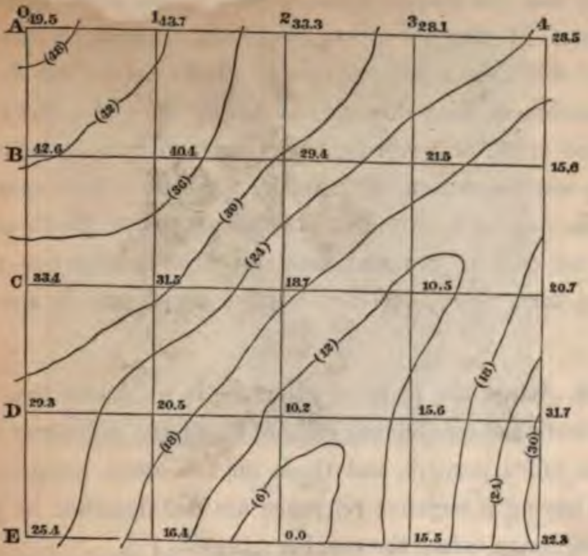

FIG. 158.

343. A practical application of this method is also called for when a surveyor is required to determine, in advance, the area of land which will be submerged by the construction of a dam. In this case the contour plane is fixed by the proposed height of the dam. Having set up at any point, a reading is taken upon the rod held upon a point at the proposed height of the dam, and the rodman is then directed to points along the shore of the proposed pond, or reservoir, which shall give the same reading. In this way the contour of the pond, when there is no overflow at the dam, can be determined. If the calculated depth of water upon the dam at the maximum overflow be added to the rod reading used above, the high-water contour may be also traced out.

344. When the plane of reference is so chosen that points of the work fall on different sides of it, all the references on one side are called positive, and those on the other, negative. The curves having a negative reference are distinguished by placing the minus sign before the number; thus — ( ).

Shading and Delineation.

345. Fig. 159 represents a piece of ground sloping towards *D*, which is the lowest point; and through this point the plane of reference is supposed to pass. The following table indicates the heights of the several points above the plane of reference.

		Ft.			Ft.			Ft.			Ft.
c	above	*D*, 2	*H*	above	*D*, 7	*p*	above	*D*, 9	*B*	about	*D*, 12
d	"	*D*, 4	*k*	"	*D*, 7	*q*	"	*D*, 9	*L*	"	*D*, 13
h	"	*D*, 4	*s*	"	*D*, 7	*C*	"	*D*, 9	*G*	"	*D*, 14
t	"	*D*, 4	*f*	"	*D*, 8	*n*	"	*D*, 11	*a*	"	*D*, 15
g	"	*D*, 5	*I*	"	*D*, 8	*i*	"	*D*, 12	*F*	"	*D*, 15
l	"	*D*, 5	*b*	"	*D*, 9	*m*	"	*D*, 12	*E*	"	*D*, 17

A above *D*, 20 feet,

The first horizontal plane is passed 2 feet above *D*, and the curve of intersection with the surface passes through *c*. The second secant plane is passed at 3 feet above *D*, and intersects the surface, in the curve *uv*, and also near *d*, which is one foot above the curve. All the other secant planes are passed at three feet from each other; and, comparing the height of each point above *D*, with the curves lying nearest, on either side, the positions of all the points, with respect to the curves, and with respect to each other, are easily seen.

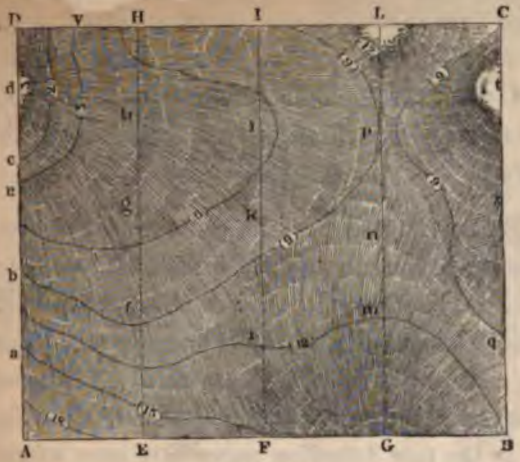

FIG. 159.

346. The manner of shading the map, so as to indicate the hills and slopes, consists in drawing the lines of shading perpendicular to the horizontal curves, as already explained (Art. **337**). These shading lines are drawn close together, when the slope is abrupt, and further apart, as it grows more gentle. Figure 159 indicates the method of shading.

347. In topographical surveys, great care should be taken to leave some *permanent marks*, with their levels written on them in a durable manner. For example, if there are any rocks, let one or more of them be smoothed, and the vertical distance from the plane of reference marked thereon; or let the vertical distance of a point on some prominent building be ascertained and marked permanently on the building. Such points should also be noted on the map, so that a person, although unacquainted with the ground, could by means of the map go upon it and trace out all the points, together with their differences of level.

348. Besides representing the contour of the ground, it is often necessary to make a map which shall indicate the woodland, the marsh, roads, ditches, etc. For this, certain characters, or conventional signs, have been agreed upon, as the representatives of things, and when these are once fixed in the mind, they readily suggest the objects for which they stand. Those which are given in the four following pages have been adopted by the U. S. Coast and Geodetic Survey, and are used in all plans and maps made under its direction.

It is very desirable that a uniform method of delineation should be adopted, and it is, therefore, recommended that the conventional signs given in the accompanying plates be carefully studied and uniformly followed.

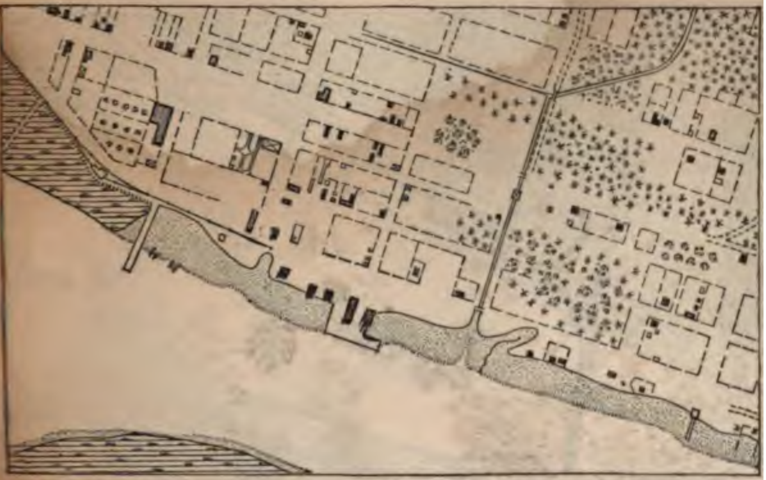

FIG. 160.—Sparsely settled Town, Salt Marsh, Pine Woods, Ditches, Fences, and Undefined Roads.

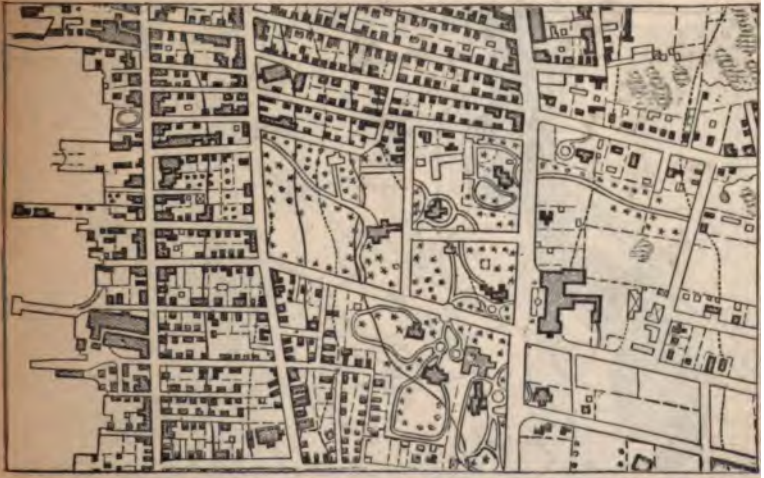

FIG. 161.—Blocking of Cities, Large Buildings, Suburban Villas and Grounds, Fresh Marsh.

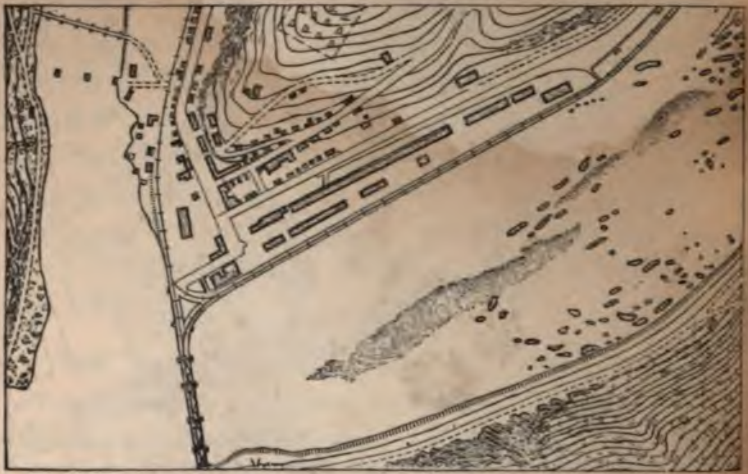

FIG. 162.—Railroads, Canals, Iron bridges, Rocky-cliffs, Mid-river drift, Water-worn Rocks, Mixed Woods over hill curves.

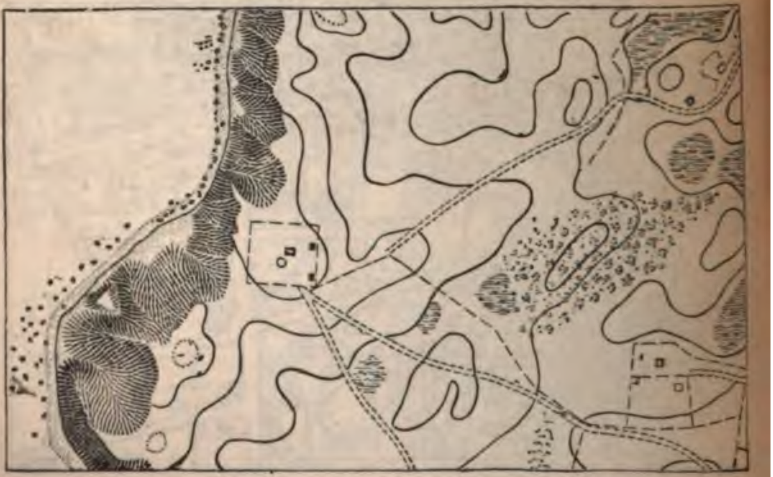

FIG. 163.—Eroded drift banks, with boulders set free; and scrub deciduous woods.

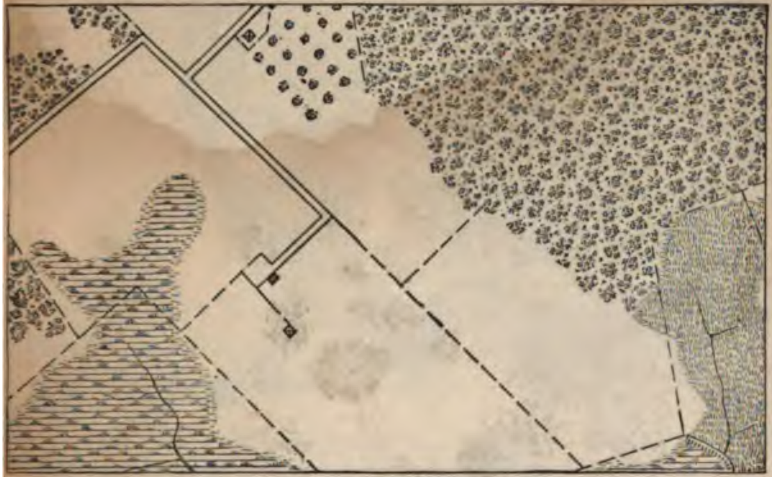

FIG. 164.—Heavy Oak Woods, Reclaimed Marsh, and Orchards.

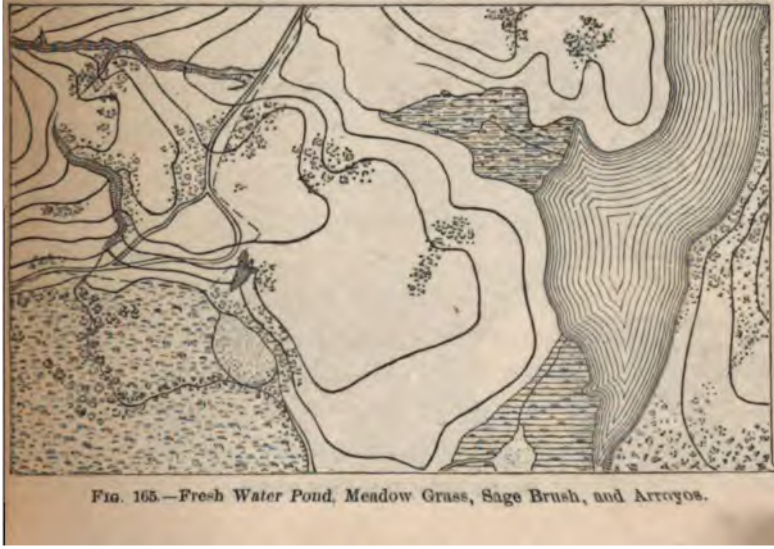

FIG. 165.—Fresh Water Pond, Meadow Grass, Sage Brush, and Arroyos.

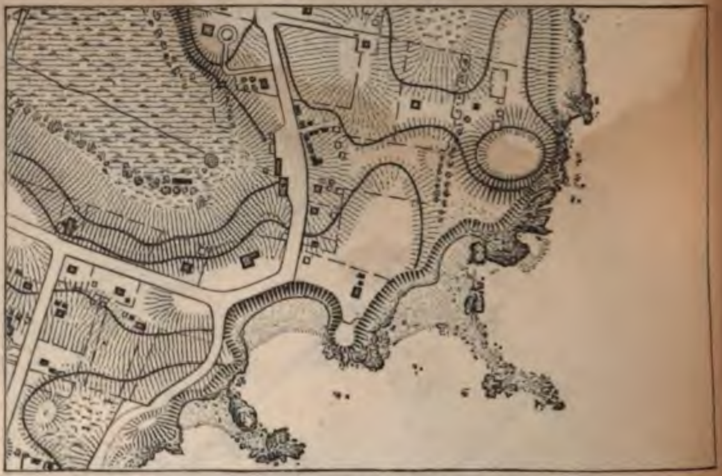

FIG. 166.—Sand and Shingle Beaches, Eroded Earth Banks, Roads, Fences, Shaded Roadsides, Hill-shading.

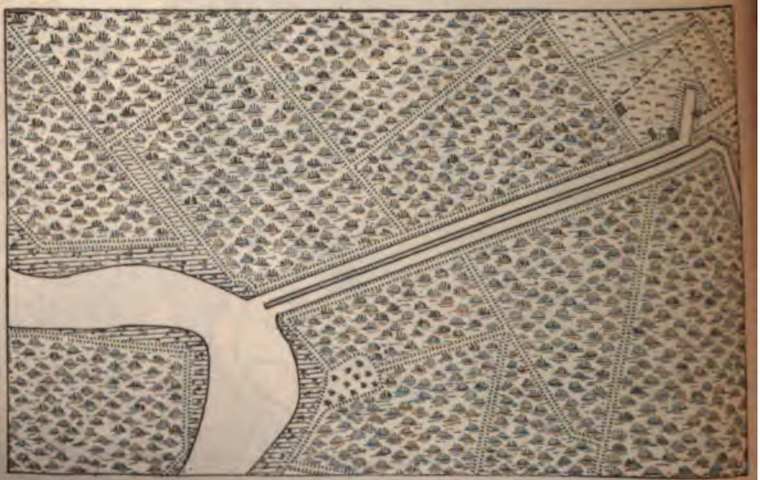

FIG. 167.—Rice, Dykes, and Ditches.

BOOK IX.

RAILWAY CURVES.

349. After the route of a railroad or canal has been determined by *reconnaissance,* the centre line of the work is established by a transit (see Section III, B. IV).

350. This preliminary survey establishes a succession of straight lines, of greater or less length, according to the obstacles to be avoided or the advantages to be gained, arising from the nature and the contour of the ground.

The angle formed, at each change in the direction of the route, is carefully measured and recorded.

In the final survey or location, these angles are replaced by curves; and in order that the change in direction shall be as gradual as practicable, the straight lines of direction are made tangents to the curves at their point of meeting.

The preliminary survey is termed, by the engineer, "running out tangents."

351. We will proceed to describe the method of locating curves, first giving the mathematical principles applicable to the subject.

Let AD and DB, Fig. 168, be two tangents to the arc of a circle, AB. Draw the radii AC, BC, and the secant CD.

The following relations are easily deduced. The tangents AD and DB are equal (Leg., Bk. III, Prob. 14). The angles A and B are right angles (Leg., Bk. III, Prop. 9), consequently the angles C and D, of the quadrilateral ADBC, must be sup-

3. What is the degree of curvature in the last example? Formula (3) gives

$$c = \frac{5729.58}{r} = 2.558° = 2° \; 33' \; 29''.$$

4. The angle a being 20° 21′, what is the value of d for a one-degree curve? *Ans.*

Location of Curves by one Transit.

354. The location of curves, according to the most common method, consists in laying off, at the point of tangency A, such angles as shall just subtend one chain of arc.

If the arcs Av, vw, wx, &c., Fig. 169, represent arcs of one chain each, the angles ACv, vCw, &c., are each equal to the degree of curvature.

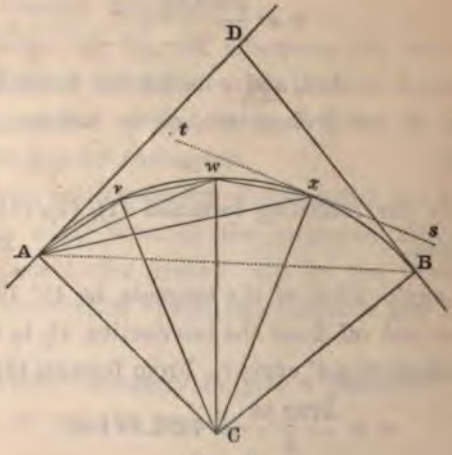

FIG. 169.

The angles DAv, vAw, wAx, are each equal to one-half the degree of curvature (Leg., Bk. III, Prop. 7, Sch., and Prop. 21).

The operations in the field are very simple. The party should consist of a transitman, two chainmen, and an axe-man.

The transit is set and adjusted at a tangent point, as A, and directed along the tangent toward D.

An angle equal to half the degree of curvature is deflected from AD toward the side on which the curve is to run. The hind-chainman holds his end of the chain at A. The fore-chainman, keeping the chain carefully extended, is directed by the transitman into line with the axis of the telescope. This locates the point v on the curve.

From the line Av, another deflection is now made, of the same angle as before. The chainmen move forward; the hind-chainman stopping at v, while the fore-chainman, keeping the chain extended, is directed by the transitman as before, and a second stake, w, is fixed on the curve.

By continuing the process of deflecting angles equal to half the degree of curvature, and causing these angles to subtend measured distances of one chain each, the entire curve is located.

355. The last deflection on the curve rarely corresponds to an entire chain; it is, therefore, less than the others. Its amount can be readily calculated, when it is remembered that the sum of all the deflections, or the angle DAB, is exactly equal to one-half the angle a.

Hence, if from $\frac{a}{2}$ the sum of the deflection angles laid off be subtracted, the remainder will be the final deflection angle, called the *sub-deflection angle.* The corresponding *sub-chord* is such part of 100 ft. as the *sub-deflection angle* is of the *deflection angle.* In practice the sub-chord should always be laid off, using the sub-deflection angle, to check the work; the final peg, thus located, should fall upon the previously determined tangent-peg.

By this method of laying out curves, any error in chaining any one chord is carried into all succeeding portions of the curve.

356. It is sometimes necessary to remove the transit from the transit-point to some other point on the curve, before the location has been completed.

In such a case, the direction of the tangent to this new point should be determined. Suppose x, Fig. 169, to be a located point on the curve to which the transit has been transferred, and from which new points beyond x are to be located. Adjust the transit and direct the telescope to A. Lay off the angle Axt, equal to DAx (the sum of the deflections made in locating v, w, and x),—xt is the tangent. By revolving the telescope, the tangent is produced to s, from which deflections may be made as at first.

NOTE 1.—The selection of the radius is governed by circumstances. Curves of the longest possible radius are, in railroads, always the most desirable; but the larger the radius for any particular pair of tangents, the greater the distance by which the curve will depart from the intersection of the tangents. It may happen, therefore, that too large a radius may lead to an obstacle, which the angle in the first survey was made to avoid.

The map, therefore, of the preliminary survey, should include so much of the topography of the adjacent section, that the radii of the curves may be selected by an inspection of the map.

NOTE 2.—It will be observed that it is the chord, and not the arc, that is measured for each deflection, when locating in the field; the difference, in railway curves, of proper dimensions, does not lead to sensible error.

For curves of a short radius (less than two thousand feet), the error may be diminished, by locating the stakes at half-chain distances, deflecting, of course, half the calculated deflection angle.

Location of Curves by two Transits.

357. The surface, over which it is necessary to locate a curve, may be of such a character as to render it impracticable for the chainmen to make their measurements; if, however, the various points are accessible to the axeman, as in the case of marshes, shallow lakes, or bays, the stakes may be accurately located by the simultaneous deflections of two transits.

The method is based on the following geometrical principle :

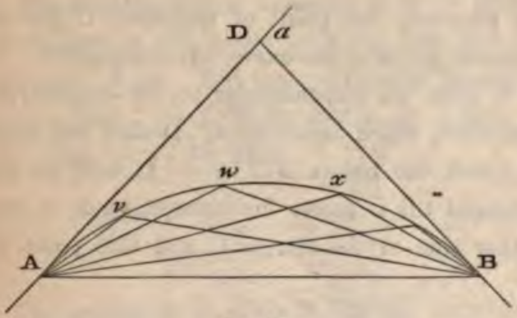

Fig. 170.

Let *A* and *B* be the two tangent points of the curve *AvB*, and *D* the intersection of the tangents.

If from any point *v*, on the curve, the lines *vA*, *vB*, be drawn, then the sum of the angles *vAB* and *vBA* is measured by one-half the arc *AB*, and is therefore equal to one-half the angle *a*, or to either of the entire angles *A* or *B*.

To locate the curve in the field, a transit is set at each of the tangent points *A* and *B*, and the deflection angle is determined as in the first method.

The transitman at *A* deflects, in the usual way, one deflection angle from the tangent *AD*. At the same time, the transitman at *B* deflects the same angle from the chord *BA*, or what amounts to the same, he deflects the difference between this angle and $\frac{1}{2}a$, from the tangent *BD*. The lines of sight of the two telescopes now intersect at a point v, on the curve, one chain from A. The flagman, directed at the same time by both transitmen, is readily brought to the location of the point. By a repetition of this process the entire curve is located.

Location of Curves by the Chain alone.

358. It is sometimes convenient to locate a curve without using the transit. In such case, the following method is generally employed.

Let A represent the point of tangency, C the centre, and v, w, x, located points of the curve, one chain apart.

From v, draw vu perpendicular to the tangent, and it will be the first offset, which denote by o. Denote the length of the chain by l, and the radius AC, by r. If, now, we suppose AC to be prolonged till it meets the circumference in some point, on the other side of the centre C, and this point then to be joined with v, and vn then drawn parallel to the tangent, we shall have (Leg., Bk. IV, P. 23),

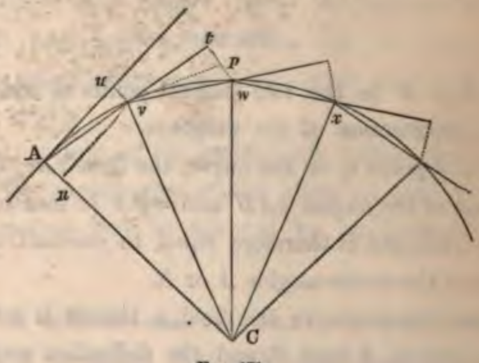

FIG. 171.

$$Av^2 = 2r \cdot An\,; \quad \text{hence,} \quad o = \frac{l^2}{2r}. \tag{4}$$

If, now, we prolong Av till $vt = Av$, and join t and w, *tw* will be the second offset, and will be double *vu*. For, the triangles in the figure, whose vertices are *C*, and whose bases are the equal chords *Av*, *vw*, &c., are isosceles and equal. Now, in any one of the triangles, the sum of the two angles at the base and the vertical angle *C*, is equal to two right-angles. But, since *Avt* is a straight line, $tvw + wvC + CvA$, is also equal to two right angles. Therefore, *tvw* is equal to any one of the equal angles at *C*, and is, consequently, double the angle *uAv*, which is half the angle *C*.

Since the triangle *wvt* is isosceles, if *vp* be drawn perpendicular to the base, it will bisect both the base and the vertical angle, making $tp = pw$. But the right-angled triangles *Auv* and *vtp* are equal (Leg., Bk. I, P. 6); hence, $tw = 2vu$. Denoting the second offset by o', we have,

$$o' = \frac{l^2}{r}. \qquad (5)$$

359. The practice is as follows: Having calculated the first offset *o*, fix one end of the chain at *A*, Fig. 171, and stretch the chain to *v*, measuring $uv = o$ perpendicular to the tangent; the measurement of *o* may be made with a short supplementary steel tape, its end division being marked to hundredths of a foot, or with a rod marked with two divisions each equal to *o*. Next hold one end of the chain at *v* and align a pin at *t*, on *Av* prolonged, making $vt = Av$; then swing the chain towards *w* till the measured distance $tw = 2o = o'$. Prolong *vw* as before and find a new point *x*, and so continue till all the full chords have been laid down. The last chord is usually a *sub-chord* and its offset must be calculated separately. Suppose it is required to run a curve of 1000 feet radius, the angle of intersection, *a*, Fig. 170, being 48°. From the formula $d = r \tan \frac{a}{2}$ we find $DA =$ 445.2, and then locate the tangent peg at *A*, and also that at

We also find $o = 5$ and $o' = 10$. The angle at the centre subtended by the 100-ft. chain is found by the relation $\frac{\frac{1}{2}\text{ chord}}{r} =$ sine $\frac{1}{2}$ angle at centre (Leg., Trig., Art. 64). In the case supposed we find the angle subtended to be 5° 44′. The number of full chords is equal to $\frac{48^\circ}{5^\circ\ 44'}$, which gives 8 full chords, and a remaining angle at the centre of 2° 8′. To find the sub-chord we have

$$\text{sine}\left(\frac{2^\circ\ 8'}{2}\right) \times 1000 \times 2 = 37.24 \text{ feet.}$$

The final offset is $\frac{(37.24)^2}{r} = 1.39$.

The peg at the end of the sub-chord should fall at the second tangent peg, if no errors have been made in chaining.

NOTE.—In employing this method of locating curves, the aligning by which the chords are produced should be done with much care, as any error in locating a stake involves much greater and increasing errors in succeeding stakes.

This is called, by engineers, "the method by offsetting from tangent and chords produced."

EXAMPLES.

1. What are the tangent and chord offsets, for a curve of 2000 feet radius; the stakes to be 100 feet apart?

Ans. From tangent, 2.5 ft.; from chord produced, 5 ft.

2. Find offsets for a one-degree curve.

Ans. Tangent, .87 ft.; chord, 1.74 ft.

360. Let it be required to run out a curve of 500 ft. radius, the stations being 25 feet apart on the curve.

As the chord of the angle i is to be 25 ft., we have (Fig. 172),

$$\text{sine } \frac{i}{2} = \frac{12\frac{1}{2}}{500} = .025$$

from which we find $i = 2° 52'$. Now,

$$Tx = bs = \text{sine } i \times 500 = 25 \text{ feet};$$

and $$xb = Ts = 500 - (\cos i \times 500) = .63 \text{ ft.}$$

Measure from T 25 feet to x, and at x lay off the perpendicular $xb = .63$ ft., thus locating the point b on the curve. To locate c we have

$$Ty = wc = \sin 2\,i \times 500$$
$$= 49.95 \text{ ft., and}$$

$$yc = Tw = 500 - (\cos 2i \times 500)$$
$$= 2.50 \text{ ft.}$$

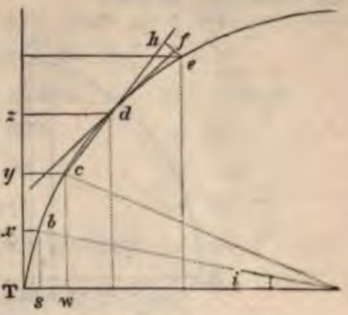

FIG. 172.

The next tangent distance to z equals sine $3i \times 500$, and the offset at z equals $500-(\cos 3i \times 500)$, and so on for succeeding points.

When the offsets become too long to be readily and correctly set out, a new tangent is located thus: Prolong cd to h making $dh = cd$, and then bisect he (e having been already located) in f and range a line df, which line will be tangent to the curve at d. The correctness of the new tangent should always be checked by locating from it the third or fourth station counting back towards T. The same computed values that were used in locating the points already fixed may be again used in locating new points from the new tangent.

Laying off the Ordinates.

361. The methods described thus far for locating railway curves, apply to points 100 feet apart. This is sufficiently accurate for the earthwork. In laying the track, however, stakes every ten or twelve feet are necessary. These are set by drawing the chain or tape in a straight line between the 100-ft. stakes, and measuring from it, offsets, as often as desirable, to the intermediate points of the curve.

The length of these offsets, or ordinates, is calculated in the following manner:

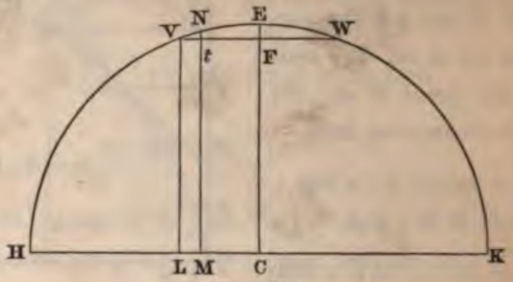

FIG. 173.

Let VW represent a 100-ft. chord of a railway curve, of which C is the centre. Draw the diameter HK parallel to VW, and drop the perpendicular VL. Then,

$$VL^2 = HL \times LK.$$

(Legendre, Bk. IV., Prop. 23, cor. 2). Since

$$HL = r - 50,$$

and $$LK = r + 50,$$

the value of VL is readily calculated for known values of the radius.

Let NM be an ordinate, at any distance from VL, say 10 feet. Then,

$$NM^2 = HM \times MK;$$

whence, $$NM^2 = (r - 40)(r + 40).$$

Having determined NM, subtract VL from it, and we have Nt, one of the ordinates required.

In this manner, by calculating the full ordinate to the diameter, and subtracting VL, any desired number of offsets are determined for the half chain VF. For FW, the ordinates have the same length, but are located in the inverse order.

The middle ordinate, FE, is found by subtracting VL from the radius.

EXAMPLE.

Determine the ordinates 10 feet apart on a 100-foot chord, for a two-degree curve. Radius, 2864.79 feet.

Ans. At 10 feet = .15 feet.
At 20 " = .28 "
At 30 " = .36 "
At 40 " = .42 "
Middle ordinate = .43 "

Reversed and Compound Curves.*

362. Two curves, of the same or different radii, may join each other and have a common tangent at the point of junction. If the curves lie on *opposite* sides of the common tangent, they form a *reversed* curve, and their radii may be equal or unequal; if they lie on the *same* side of the common tangent, they have unequal radii and form a *compound* curve. Thus ABC (Fig. 174) is a reversed curve, and ABD a compound curve.

The point of contact of the common tangent is called, in a reversed curve, the reversing point, and, in a compound curve, the common tangent point or the point of compound curvature.

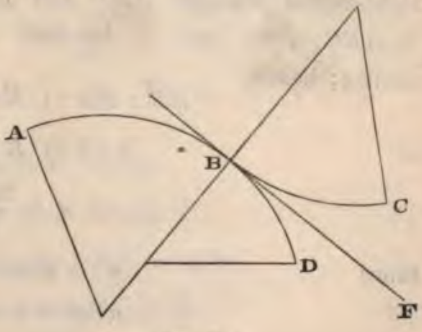

Fig. 174.

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* Taken, by permission and with slight alterations, from Henck's "Field Book for Railroad Engineers."

The reversing point of a reversed curve contained between parallel tangents is in the line joining the tangent points. Thus, in the curve *ACB*, Fig. 175, contained between the parallel tangents *HA* and *BK*, the reversing point, *C*, is in the line *AB* joining the points of contact *A* and *B*.

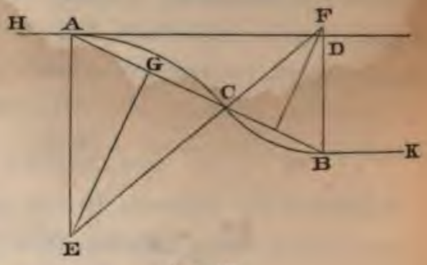


FIG. 175.

A reversed curve is of use in certain track-work near stations, constructing turnouts, &c., though it is not, or ought not to be, used on the ordinary running track.

363. *Given the perpendicular distance between two parallel tangents $BD = b$ (Fig. 175), the distance between the two tangent points $AB = a$, and the first radius, $EC = R$, of a reversed curve uniting the tangents HA and BK, to find the chords $AC = a'$ and $CB = a''$, and the second radius $CF = R'$.*

Draw the perpendiculars *EG* and *FL* (Fig. 175). Then the right-angled triangles *ABD* and *EAG* have the angle $BAD = AEG$, since each is one-half *AEC*, and are, therefore, similar; hence,

$$AB : BD :: EA : AG,$$

or

$$a : b :: R : \tfrac{1}{2}a'.$$

$$\therefore\ a' = \frac{2Rb}{a}. \qquad (1)$$

Since

$$a'' + a' = a,$$

$$a'' = a - a'. \qquad (2)$$

To find R', we have, from the similar triangles *ABD* and *FBL*,

$$a : b :: R' : \tfrac{1}{2}a''.$$

$$\therefore \quad R' = \frac{aa''}{2b}. \qquad (3)$$

Any three of the quantities a, a', a'', b, R, R', being given, the others may be found from equations (1), (2), (3).

EXAMPLES.

1. $b = 8$, $a = 160$, $R = 900$; find a', a'', R'.
$a' = 90$; $a'' = 70$; $R' = 700$.

2. $b = 8$, $a' = 90$, $a'' = 70$; find a, R, R'.

3. $R = 900$, $R' = 700$, $b = 8$; find a, a', a''.

364. *Given the line $AB = a$ (Fig. 176), which joins the fixed tangent points A and B, the angle $DAB = A$, and the angle $ABG = B$, to find the common radius $EC = CF = R$ of a reversed curve to unite the tangents HA and BL.*

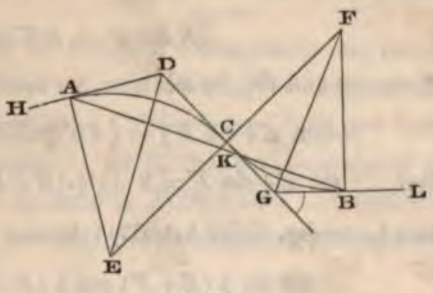


FIG. 176.

From the triangle AEK, Fig. 176, we have (Art. **32**),

$$AE : EK :: \sin AKE : \sin EAK;$$

but since

$$EAK = 90° - A,$$

$$\sin EAK = \cos A;$$

hence, denoting angle AKE by K, we have,

$$EK \cdot \sin K = R \cdot \cos A. \qquad (1)$$

In like manner, from the triangle BFK, we have,

$$FK \cdot \sin K = R \cdot \cos B. \qquad (2)$$

From (1) and (2), by addition, we have,

$$(EK + FK) \sin K = 2R \sin K = R (\cos A + \cos B). \qquad (3)$$

$$\therefore\quad \sin K = \tfrac{1}{2}(\cos A + \cos B). \tag{4}$$

But $\quad \cos A + \cos B = 2\cos\tfrac{1}{2}(A+B)\cos\tfrac{1}{2}(A-B),$

(see Legendre, Trig. Art **67**); hence,

$$\sin K = \cos\tfrac{1}{2}(A+B)\cos\tfrac{1}{2}(A-B). \tag{5}$$

Having found K, we have the angle

$$\begin{aligned} AEK = E = 180^\circ - (K + EAK) &= 180^\circ - (K + 90^\circ - A) \\ &= 90^\circ + A - K. \end{aligned} \tag{6}$$

In like manner, the angle

$$BFK = F = 90^\circ + B - K. \tag{7}$$

From the triangle AEK, we have

$$AE : AK :: \sin K : \sin E.$$

$$\therefore\quad R\sin E = AK\sin K. \tag{8}$$

In like manner, from triangle BFK, we have,

$$R\sin F = BK\sin K. \tag{9}$$

From (8) and (9), by addition, we have

$$R(\sin E + \sin F) = (AK + BK)\sin K = a\sin K. \tag{10}$$

But, $\quad \sin E + \sin F = 2\sin\tfrac{1}{2}(E+F)\cos\tfrac{1}{2}(E-F),$

(see Legendre, Trig. Art. **67**); hence,

$$2R\sin\tfrac{1}{2}(E+F)\cos\tfrac{1}{2}(E-F) = a\sin K.$$

$$\therefore\quad R = \frac{\tfrac{1}{2}a\sin K}{\sin\tfrac{1}{2}(E+F)\cos\tfrac{1}{2}(E-F)}. \tag{11}$$

Substituting in (11) the values of E and F from (6) and (7), we have

$$R = \frac{\tfrac{1}{2}a\sin K}{\cos\left[K - \tfrac{1}{2}(A+B)\right]\cos\tfrac{1}{2}(A-B)}. \tag{12}$$

EXAMPLE.—Given $a = 1500$, $A = 18^\circ$, $B = 6^\circ$; find R.

From equation (4), K is found to be $76^\circ\ 36'\ 10''$, and then from (12), R is found to be 1710.48.

365. *If one branch of a compound curve be produced until the tangent at its extremity is parallel to the tangent at the extremity of the second branch, the common tangent point of the two arcs is in the straight line produced which passes through the tangent points of these parallel tangents.*

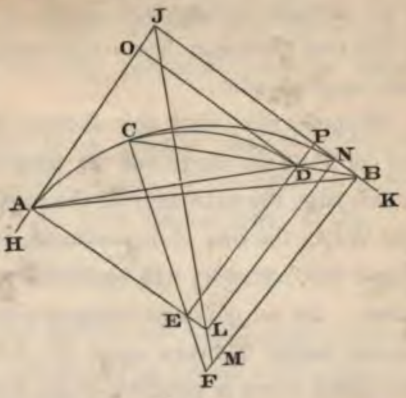


FIG. 177.

Let *ACB*, Fig. 177, be a compound curve uniting the tangents *HA* and *BK*. The radii *EC* and *FC*, being perpendicular to the common tangent at *C*, the point of compound curvature, are in the same straight line. Continue the curve *AC* to *D*, where its tangent *OD* becomes parallel to *BK*, and consequently the radius *ED* parallel to *FB*. Then if the chords *CD* and *CB* be drawn, we have the angle $CED = CFB$, whence *ECD*, the half-supplement of *CED*, is equal to *FCB*, the half-supplement of *CFB*. But *ECD* can not be equal to *FCB*, unless *CD* coincides with *CB*; therefore, the line *BD* produced passes through the common tangent point *C*.

366. *To find a limit in one direction of each radius of a compound curve.*

Let *AI* and *BI*, Fig. 177, be the tangents of the curve; draw *IM* bisecting the angle *AIB*; draw *AL* and *BM* perpendicular respectively to *AI* and *BI*, meeting *IM* in *L* and *M*. Then the radius of the branch commencing on the shorter tangent, *AI*, must be *less* than *AL*, and the radius of the branch commencing on the longer tangent, *BI*, must be *greater* than *BM*.

For, suppose the shorter radius equal to AL, and hence, IN equal to AI; join LN, then the equal triangles AIL and NIL give $AL = LN$; so that the curve, if continued, will pass through N, where its tangent will coincide with IN. Then (Art. **365**) the common tangent point would be the intersection of the straight line through B and N with the first curve; but in this case there can be no intersection, and therefore no common tangent point.

Suppose, next, that this shorter radius is greater than AL, and continue the curve till its tangent becomes parallel to BI. In this case, the extremity of the curve will fall outside the tangent BI in the line AN produced, and a straight line through B and this extremity will again fail to intersect the curve already drawn. As no common tangent point can be found when the shorter radius is taken equal to AL, or greater than AL, no compound curve is possible. This radius must, therefore, be *less* than AL.

In like manner it may be shown that the radius of the other branch of the curve must be *greater* than BM.

If the tangents AI and BI, and the intersection angle I are known, then

$$AL = AI \tan \tfrac{1}{2}I;$$

$$BM = BI \tan \tfrac{1}{2}I.$$

These values are, therefore, the limits of the radii in one direction.

367. If nothing were given but the position of the tangents and the tangent points, it is evident that an indefinite number of different compound curves might connect the tangent points; for the shorter radius might be taken of any length less than the limit found above, and a corresponding value for the greater could be found. Some other condition must, therefore, be introduced, as, for example, in the following problem:

368. *Given the line* $AB = a$ (Fig. 177), *which joins the fixed tangent points* A *and* B, *the angle* $BAI = A$, *the angle* $ABI = B$, *and the first radius* $AE = R$, *to find the second radius* $BF = R'$ *of a compound curve to unite the tangents* HA *and* BK.

Let the first curve be run with the given radius from A to D, where its tangent DO becomes parallel to BI; then the common tangent point C is in the line BD produced, and the chord $CB = CD + BD$.

The angle OAD, formed by a tangent and a chord, is measured by half the arc ACD; hence, $R \sin OAD = R \sin IAD = \frac{1}{2} AD$ (see Legendre, Trig. Arts. **64** and **30**); hence,

$$AD = 2R \sin IAD. \tag{1}$$

In the triangle OAD, since OA and OD are equal, angle $AOD = 180° - 2OAD$; hence, $OAD = IAD = 90° - \frac{1}{2}AOD = 90° - \frac{1}{2}AIB$; but from the triangle AIB, $\frac{1}{2}AIB = 90° - \frac{1}{2}(A+B)$;

whence the angle $$IAD = \tfrac{1}{2}(A+B). \tag{2}$$

From (1) and (2), we have

$$AD = 2R \sin \tfrac{1}{2}(A+B). \tag{3}$$

Then in the triangle ABD, we have $AB = a$, $AD = 2R \sin \frac{1}{2}(A+B)$, and the included angle

$$DAB = IAB - IAD = A - \tfrac{1}{2}(A+B) = \tfrac{1}{2}(A-B);$$

whence, we have the proportion (Legendre, Trig. Art. **45**),

$$\begin{aligned} AB + AD : AB - AD \; :: \; &\tan \tfrac{1}{2}(ADB + ABD) \\ &: \tan \tfrac{1}{2}(ADB - ABD). \end{aligned} \tag{4}$$

$\frac{1}{2}(ADB + ABD) = \frac{1}{2}(180° - DAB)$; $\frac{1}{2}(ADB - ABD)$ may be found from (4); and from the half-sum and half-difference thus obtained, the angles ADB and ABD may be found. These angles being known the side BD may be found from the proportion (Art. **32**),

$$\sin ABD : \sin DAB :: AD : BD.$$

The angle $CBI = B - ABD.$

Again, as above, $CB = 2R' \sin CBI,$

and $CD = 2R \sin CDO = 2R \sin CBI.$

Substituting these values of CB and CD, in the equation

$$CB = CD + BD,$$

we have $2R' \sin CBI = 2R \sin CBI + BD.$

$$\therefore \quad R' = R + \frac{BD}{2 \sin CBI}; \tag{5}$$

or

$$2(R' - R) = \frac{BD}{\sin CBI}. \tag{6}$$

When the angle B is greater than A, that is, when the greater radius is given, the solution is the same except that the angle $DAB = \frac{1}{2}(B - A)$, and CBI is found by subtracting the *supplement* of ABD from B. We shall also find $CB = CD - BD$; hence,

$$R' = R - \frac{BD}{2 \sin CBI}; \tag{7}$$

or

$$2(R - R') = \frac{BD}{\sin CBI}.$$

NOTE.—If more convenient, the point D may be determined in the field by laying off the angle $IAD = \frac{1}{2}(A + B)$, and measuring the distance $AD = 2R \sin \frac{1}{2}(A + B)$. BD and CBI may then be measured, instead of being calculated as above.

EXAMPLE. $a = 950$, $A = 8°$, $B = 7°$, $R = 3000$; find R'.

$$AD = 2 \times 3000 \sin \tfrac{1}{2}(8° + 7°) = 783.16$$

and $$DAB = \tfrac{1}{2}(8^\circ - 7^\circ) = 30'.$$

Then, to find ABD, we have

$$\begin{array}{lll}
 & \log (AB - AD),\ 166.84 & = 2.222300 \\
 & \log \tan \tfrac{1}{2}(ADB + ABD),\ 89^\circ\ 45' & = 2.360180 \\
\text{(a. c.)} & \log (AB + AD),\ 1733.16 & = \underline{6.761161} \\
 & \log \tan \tfrac{1}{2}(ADB - ABD),\ 87^\circ\ 24'\ 17'' & = \underline{1.343641}
\end{array}$$

$$\therefore\ ABD = 2^\circ\ 20'\ 43'';$$

whence, $$CBI = B - ABD = 4^\circ\ 39'\ 17''.$$

Next, to find BD,

$$\begin{array}{lll}
 & \log AD\ (783.16) & = 2.893849 \\
 & \log \sin DAB\ (30') & = 7.940842 \\
\text{(a. c.)} & \log \sin ABD\ (2^\circ\ 20'\ 43'') & = \underline{1.388052} \\
 & \log BD\ (167.01) & = \underline{2.222743}
\end{array}$$

Then, from (6), we have

$$\begin{array}{lll}
 & \log BD\ (167.01) & = 2.222743 \\
\text{(a. c.)} & \log CBI\ (4^\circ\ 39'\ 17'') & = \underline{1.090708} \\
 & \log 2\,(R' - R),\ 2058.03 & = \underline{3.313451}
\end{array}$$

$$\therefore\ R' - R = 1029.01;$$

$$R' = 3000 + 1029.01 = 4029.01.$$

BOOK X.

MINING SURVEYING.

SECTION I.

DEFINITIONS AND GENERAL PRINCIPLES.

369. Mining Surveying comprises all the operations necessary to determine the relative positions of the parts of a mine with respect to each other, and also with respect to the surface of the earth.

370. The general principles involved in this branch of surveying are the same as those used in surface surveying, but, from the nature of the case, certain modifications are required.

Stations are designated by lamps instead of flags, and lamp-stands instead of flag-rods, or by plumb-lines properly suspended and lighted; *station points*, if temporary, are marked by cross-lines chipped in the rock, or sometimes by simple chalk lines, and, if permanent, by iron pegs driven into holes drilled for the purpose.

The *compass* is rarely used for underground work, and ought never to be used for any but rough work, because of the inaccuracies to which it may lead. A great deal of the mining in the U. S. is done in the far West, where the magnetic declination is not known; and, further, the declination is seriously affected by the state of the atmosphere, the presence of iron ores, magnetic pyrites, &c.

The *transit*, which is the principal angular instrument employed, and the only necessary one, differs from the ordinary transit in having a diagonal eye-piece, to permit observations to be made when the telescope is directed vertically upward, and also an arrangement for illuminating the cross-wires.

A method of lighting the cross-wires is by the reflector shown in Fig. 178. This is an elliptical piece of brass, silver-plated on the under side, and inclined at an angle of 45° to its ring, which is fitted to the object end of the telescope; the hole in the reflector admits the use of the telescope, while a light held near the under surface illuminates the cross-wires.

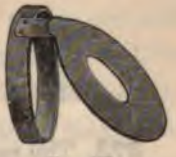


FIG. 178.

The transit should be furnished with a solar attachment (see Appendix A) for establishing the true meridian and running out lines with reference thereto; and should also have an extension tripod to adapt it for use in mountain surveys, where one or more legs must be shortened, and for mines, where in many places a short tripod is indispensable.

371. Traversing is the operation of running a zigzag line, from one point to another. The elements of the traverse are straight lines, determined by their lengths and by their inclinations to certain fixed planes. In mining surveying, three such planes are used; the *first*, is either a meridian plane through the origin of the traverse, or a vertical plane through the first course; the *second*, is a horizontal plane through the origin; and the *third*, is a vertical plane through the origin, and perpendicular to the other two.

372. Working, or Reducing the Traverse, is the operation of finding the length and direction of a single line, equivalent to the zigzag, that is, starting from, and terminating at, the same points. Such a line is called the *resultant* of the traverse.

The zigzag line is run along the subterranean openings of a mine. Such openings, when vertical, are called *shafts*, and when not vertical, *tunnels*.

SECTION II.

METHOD OF LOCATING CLAIMS.

373. The methods employed in locating claims on the surface are various, and in general very crude, except when a surveyor, usually a U. S. Deputy Mineral Surveyor, is called upon to make the survey. Prospectors are usually without suitable instruments to lay off their claims with any degree of accuracy. We will,

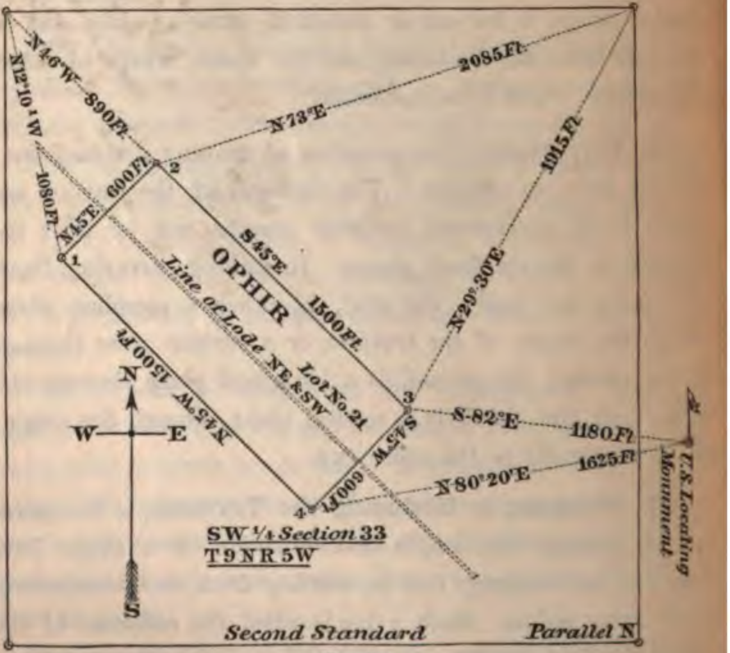


FIG. 179.

therefore, only consider the method employed by the Deputy Mineral Surveyors, who are compelled to follow the instructions received from the Land-office.

374. The mining claim shown in Fig. 179 has the dimensions allowed by the U. S. Mineral Laws, viz., 1500 feet in the direction, or on the "strike," of the vein, by 300 feet on each side of the middle of the vein at the surface. An ideal case is assumed, the exact strike is supposed to have been determined, and the side lines of the claim run parallel to it. Such cases are the exception. Generally, the strike is not accurately determined by the prospector, and claims are, in both direction and dimensions, usually but a rough approximation. The courts are lenient and allow considerable latitude in the matter. The prospector may alter the boundaries of, or "swing," his claim after the strike has been determined, provided that no trespass is committed; but when the course cannot be altered without interference with other claims, the boundaries already established must be adhered to.

When a claim is made and staked out, a record of the same must be placed on file in the office of the Recorder having charge of the records of mining locations in the district where the claim is situate; and in case the boundaries of such claim are altered, a record of the amended location must be filed in like manner.

"A failure to make and record the location in accordance with the law and regulation in force at the date of the location, will defeat the claim; and if it is not made with such definiteness as to operate as notice to all persons seeking to acquire rights to mining lands, it will be void for uncertainty" (General Land Office Instructions).

375. When mineral discoveries are made and located on surveyed land, the surveys must conform to the public survey and be connected with or "tied" to it, so that there will be no difficulty in finding some established corner. In Fig. 179, the points 1 and 2 are tied to the N. W. cor. of the quarter-section in T. 9 N. R. 5 W.

376. When discoveries are made on unsurveyed land, U. S. locating monuments are established to which the claims are tied in the same manner. These monuments may be natural objects, as mountain peaks, permanent rocks, or they may be artificially constructed, in which case they should be strong and without liability to disturbance. The method of tying to such a monument is shown in Fig. 179. When a corner is properly tied in the manner mentioned, the courses are staked out, 1500 ft. along the length of the vein by 300 ft. on each side of the same. The *end* lines must be parallel to each other in accordance with the Mining Law, but the *side* lines need not be so, though the survey of a lode "must be substantially a parallelogram."

377. Before commencing the survey for a patent, the original stakes are found, if possible; that is, if no amended location certificate has been filed. In the latter case, the stakes marking the amended location are the ones to be followed. When no stakes can be found, the surveyor will be guided by the locator or some one familiar with the boundaries of the property, provided the boundaries then pointed out do not differ from the record of the claim on file in the Recorder's office. Even in the latter case the surveyor can, at the wish of the owner, and when there is no interference with other locations, alter the claim (swing it), file an amended location notice in the Recorder's office, and send forward the description and maps of the altered claim for patent.

378. In making a survey, it is frequently found that there are conflicting claims, that is, two or more claims cross or lap over each other. An example is shown in Fig. 180, which is a plot made from actual claims on Treasure Hill, Black Hills,

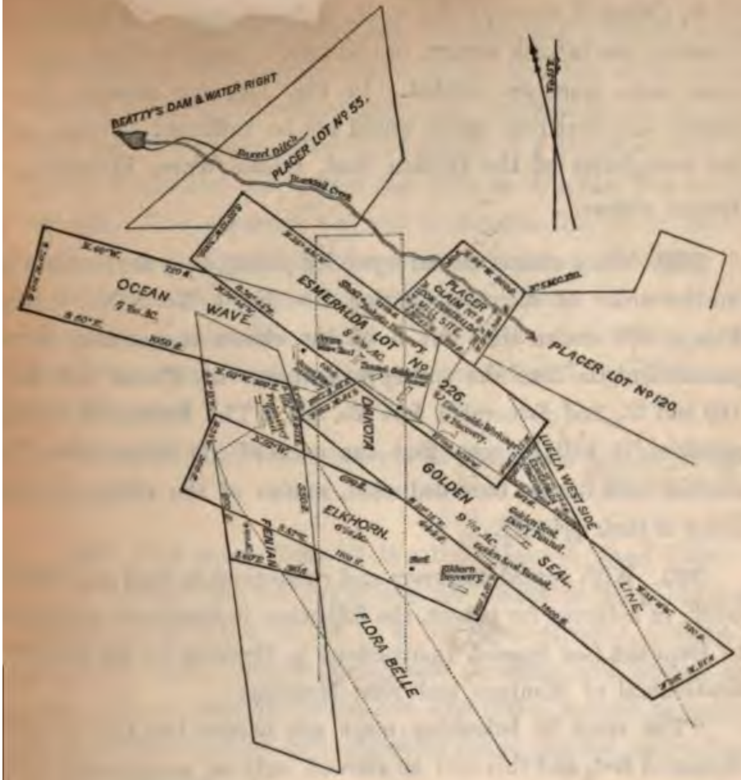


Fig. 180.

Dakota. When claims conflict, priority of location must govern as to the ownership of the surface in dispute, and the U. S. Deputy Surveyor in making his plot, etc., is required, by the land-office instructions, to show and deduct the area in conflict from the subsequent location,—as is shown in the figure. Should this not be satisfactory to the owner, his appeal is to the courts.

379. When the survey for patent is completed, the surveyor drives strong stakes, generally about 4 inches to 5 inches square, and 4 to 5 feet long, firmly into the ground, and marks them M. S. (Mineral Survey) No. 1, M. S. No. 2, etc. No less than 4 stakes, one in each corner, can be used to mark a claim, and in some cases more are needed. In Fig. 180, for example, it is readily seen that four stakes would not be sufficient to trace out the boundaries of the Golden Seal, Ocean Wave, Elkhorn, or Fenian claims.

380. When claims are surveyed for patent, they are numbered in the order of their application, Lot No. 1, No. 2, No. 3, etc. Figure 180 shows that but 3 of the claims represented were patented at the time the survey was made, viz., Placer Lot No. 120 and 55, and Esmeralda Lot No. 226. The Esmeralda being patented, it will be seen that the areas of the other claims in conflict with it have been deducted, so also of the others in the order of their priority.

381. With regard to errors and corrections in field and office work, in a survey for patent, the following instructions are given to Deputies (see Special Instructions to Deputies by the Surveyors-General of Montana and New Mexico):

"The error in balancing must not exceed two feet in one thousand feet, and this will be allowed only on complicated surveys or when the ground is very rough."

In the notes of survey returned, must be a table of area calculated by double meridian distances; in this table must be shown first the balance of the survey as actually run upon the ground, and immediately thereafter the corrected latitudes and departures. The correction must be made, either by distributing the error among the courses, in proportion to the length of each course, by the proportion—The sum of the lengths of all the courses *is to* the total error in latitude or departure *as* the length of each course *is to* the correction of its latitude or departure (see Art. **127**); or by the following method, which is considered preferable:

"You can correct the balance by computing a closing course and distance. This can be made on the last line of the survey when it is one of the longest lines, but otherwise should be made upon the longest line unless there should be a line that could not be run accurately, and in that case close on it, when you use this method. This corrected line will be the *true* line to be used in the notes and on plot. In notes you will state immediately following (parenthetically) the course and distance of the line as actually run upon the ground. This is the better way, as the actual error made in the survey can be detected by reference to this line only."

"The maximum error that will be allowed in a lode claim is 0.03 acres."

382. The instructions of the U. S. General Land Office to U. S. Deputy Mineral Surveyors are embraced in a series of decisions and letters to the U. S. Surveyors-General, relating to particular cases. Based upon these decisions and letters, and upon what in their judgment and experience seemed necessary, the Surveyors-General have generally issued printed instructions to their deputies.

A copy of the instructions of the Surveyor-General of Colorado to Deputy Mineral Surveyors, with sample Field Notes and sample Plot furnished therewith, is given in Appendix C.

SECTION III.

UNDERGROUND TRAVERSING, ETC.

383. Let it be required to sink a shaft from the surface to connect with a tunnel, which is driven into a hillside.

In many cases the needle cannot be used on account of disturbing influences, such as the proximity of iron and its ores, or magnetic pyrites. The vernier readings of the transit are then employed, and indeed this method is preferable in all cases.

Ascertain the course of the tunnel and the position of the point where it is desired to make the connection. Establish a station-stake at any convenient distance from the mouth of the tunnel that will command a sight of its centre point. If the centre line of the tunnel is a straight line, or nearly so, a sight may be taken from the established station to the point of intersection. In general, however, this cannot be done, the line of sight being cut off by deflections in the course, thus requiring a traverse.

384. Where curves occur, stations should be established by driving nails in the centre of the cap-timber, overhead in the tunnel. If there are no timbers, holes should be drilled in the rock and filled with wooden spuds into which nails are driven. Plumb-lines are then suspended from these nails, lighted by lamps suitably placed, and used for sighting to with the transit.

If desired, the selected stations may be marked by iron pegs driven into holes drilled in the floor of the tunnel. In this case, guiding lamps placed on stands similar to tripods, but with sliding pieces carrying the lamps and fixed in position by clamp-screws, [illegible] for sighting to. By the sliding and clamp arrangement, the height of the lamp may be made equal to that of the line of sight of the transit telescope.

As the same methods will apply in either case, the suspended plumb-lines will be assumed as giving, in general, better results.

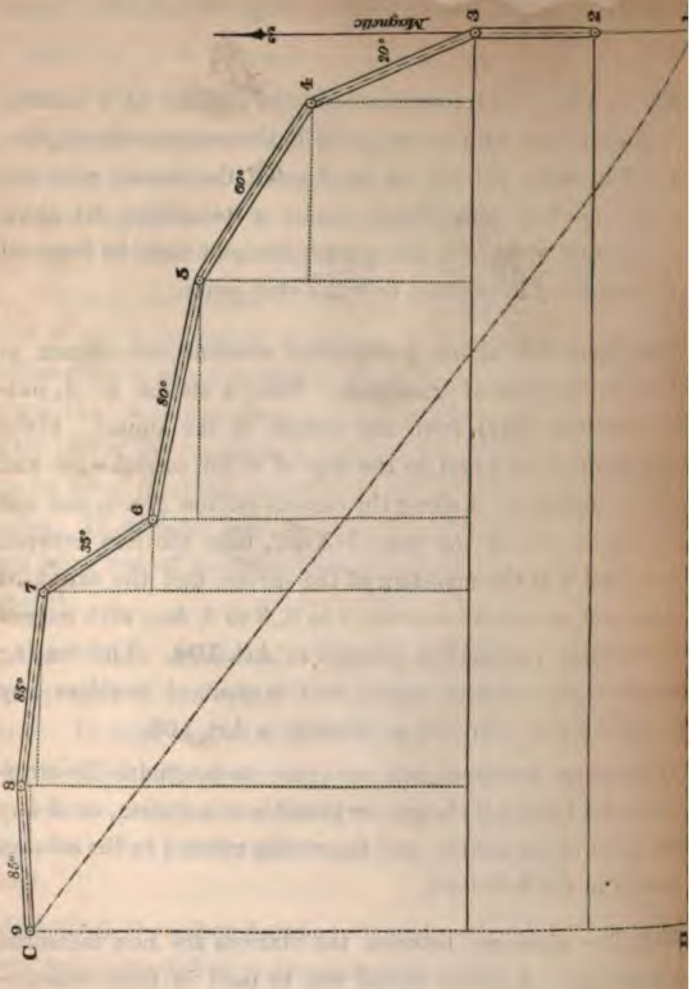
385. To place the transit accurately in position at a station, take a block of lead with a steel point in the centre projecting out about half an inch; place it on the floor of the tunnel, with the steel point upward, immediately under a plumb-bob let down from the station overhead; the plumb-line may then be removed and the transit set in position over the steel point.

386. Figure 181 shows a somewhat extreme case, chosen to illustrate the method of traversing. Take a station at *A*, outside and 100 feet (say) from the mouth of the tunnel. Fix a stake at *A*, and drive a nail in the top of it for convenience and accuracy of sighting. Calling the outside station No. 1, and the one at the mouth of the tunnel No. 2, take the line between stations 1 and 2 as the meridian of the survey, find the azimuths of the several successive courses, 2 to 3, 3 to 4, &c., with respect to this meridian, precisely as directed in Art. **194**. The bearing of the several courses with respect to this assumed meridian may then be found and tabulated as directed in Art. **195**.

If necessary, measurements are made to determine the cross-section of the tunnel, its height or breadth, at a station, or at any desired point of the course, and the results entered in the column of remarks in the field-book.

387. The distances between the stations are now measured with great care. A chain should not be used in these measurements; a light steel tape is much better. The points corresponding to the ends of the tape are marked by chalk lines on the rock, or in some other convenient manner. The distances may

be measured horizontally, or along the slope of the tunnel
which latter case they must be reduced to horizontal distance



388. When distances between stations are measured along
slope, the angle of elevation or depression of the course must
determined—and may be determined as follows:

Let the nail on staff at *A* (Fig. 181) be at the same distance above the ground at *A* that the axis of the vertical limb of the transit is above the floor of the tunnel at station 2; when the telescope is pointed to the nail at *A*, the reading of the vertical limb will be the angle of inclination of the first course, in *elevation*, if the telescope points downward—in *depression*, if it points upward. Let the point of a plumb-bob, suspended from the nail overhead at station 3, at the same distance above the floor of the tunnel at 3 that the axis of the vertical limb of the transit is above the floor at 2; when the telescope is directed to the point of the plumb-bob, the reading of the vertical limb will be the angle of inclination of the second course, in *elevation*, if the telescope points upward—in *depression*, if it points downward. In like manner are obtained the angles of elevation or depression of the several successive courses to the end of the traverse.

389. The method of recording the observations and measurements made in a traverse, is shown in the following

Field Book.

Stations.	ANGLES OF INCLINATION.		Azimuth with Course 1.2.	Distance in feet.	REMARKS.
	Elevation.	Depression.			
1	0° 0′	0° 0′	0° 0′	102	Sta. 1, at staff, outside tunnel.
2			0° 0′	100	Sta. 2, at iron peg, at mouth of tunnel overhead.
3			340°	150	
4			300°	180	
5			280°	200	At Sta. 5, breadth 6½ ft.
6			325°	120	
7			276°	162	At Sta. 7, height 7½ ft.
8			265°	120	At iron peg.
9					

The above is a record of the traverse shown in Fig. 181. The distances measured are supposed to be horizontal distances, and the angles of inclination are, therefore, zero.

390. The method of *reducing the traverse* is as follows.

From the azimuths of the several courses with the given course taken as meridian, find the bearings (see Art. **195**) and proceed as shown in the following

Office Form.

Station.	Slope in Feet.		Bearing with Course 1-2.	Length of Course.	Latitude.		Departure.	
	Elevation.	Depression.			N.	S.	E.	W.
1	0	0	North	102	102			
2			North	100	100			
3			N 20° W	150	140.95			51.30
4			N 60° W	180	90			155.88
5			N 80° W	200	34.72			196.96
6			N 35° W	120	98.30			68.83
7			N 85° W	162	14.12			161.38
8			S 85° W	120		10.46		119.54
9								
Resultant.					580.09	10.46	00	753.89
					10.46			00
			N 52°56′W	944.68	569.63			753.89

Hence the resultant course AC, from 1 to 9, has a northing of 569.63 feet and a westing of 753.89; to find its length and bearing, we have in the triangle ABC,

$$AB = 753.89 \quad \text{and} \quad BC = 569.63\,;$$

hence $$AC = \sqrt{\overline{AB}^2 + \overline{BC}^2} = 944.89.$$

$$\tan BAC = \frac{BC}{AB} = \frac{569.63}{753.89};$$

$$BAC = 37° \, 4';$$

$$\therefore \text{ bearing of } AC = 90° - 37° \, 4' = 52° \, 56'.$$

391. If the distances between stations are measured on the slope, instead of horizontally, the angle of elevation or depression of each course must be observed, and recorded in the proper column of the field book. The distances on the slope must then be reduced to horizontal distances in finding the resultant course. The method of record and reduction in such a case, and when the magnetic bearing of the course, from which azimuths are measured, is given, will be apparent from the following

EXAMPLE. Required the resultant of the traverse of which the notes are contained in the following

Field Book.

Stations.	ANGLES OF INCLINATION.		Azimuth with Course 1.2.	Distance in feet.	REMARKS.
	Elevation.	Depression.			
1		2° 30′	0° 0′	307	Sta. 1, at iron peg, centre of shaft.
2		3° 15′	176° 15′	402	
3		3° 30′	228° 30′	240	
4		4° 15′	297°	367	
5	1° 30′		246° 15′	409	
6	2° 00′		249° 45′	200	At iron peg.
7					

Let the magnetic bearing of the course, 1.2, from which azimuths are measured, be S 23° W.

Find, from the bearing of the course taken as meridian and the azimuths of the several courses, the bearings of the several courses, as in Art. **198**. The traverse is then reduced as in the following

Office Form.

Course.	Slope in Feet.		Bearing.	Reduced length of course.	Latitude.		Departure.	
	Elevation.	Depression.			N.	S.	E.	W.
1		13.4	S 23° W	306.7		282.3		119.8
2		22.8	S 19¼° W	401.4		379.0		132.0
3		14.7	S 71½° W	239.6		76.0		227.2
4		27.2	N 60° W	366.	183.0			317.0
5	10.7		S 89¼° W	408.9		5.3		408.8
6	7.		N 87¼° W	199.9	9.6			199.7
	17.7	78.1			192.6	742.6		1404.5
		17.7				192.6		0.0
Resultant.		60.4	S 68½° W	1508.3		550.0		1404.5

The length of the course on the slope, multiplied by the sine of the angle of inclination, gives the distance the course rises or falls, in feet (if the measurements are made in feet); and the length multiplied by the cosine of the angle of inclination, gives the reduced length of the course, that is, the length that would have been found had the course been measured on a horizontal line. The bearing and reduced length of each course being found, the *latitudes* and *departures* of the several courses are found as before. In this example, the resultant course descends 60.4 feet, its southing is 550 feet, and its westing 1404.5; its bearing, S. 68½° W., and length on the horizontal, 1508.3, then found as before.

392. The difference of level of two points underground m be found as shown in the example given in Art. **391**, or by running a line of levels between the points as directed in Art. **294**. Leveling rods for underground use should be painted and graduated to feet, tenths, and hundredths of a foot, and about 3½ to 5 feet in length. When reading the graduations of the rod through a telescope, the flame of two lamps, one from each side, should be brought to bear on its face so as to light it and not obstruct the line of sight of the observer.

Method of Plotting the Underground Traverse on the Surface.

393. To plot the traverse on the surface of the earth, the first course, from which azimuths were measured, must first be laid down, in direction and horizontal length, and its two ends marked with suitable pegs. If the first station has been taken outside the tunnel, as in the traverse shown in Fig. 181, the first course is already, or may easily be, pegged out on the surface. If, however, the first course is within the tunnel, as in example given in Art. **391**, the first course must be connected with the surface. There are two principal methods of making the connection:

394.—FIRST METHOD.

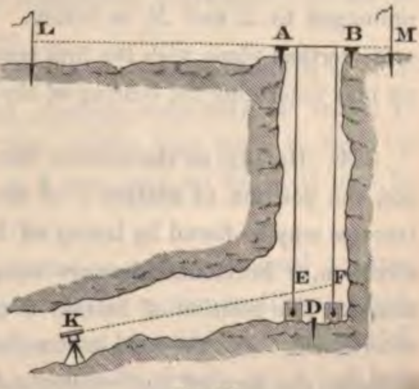


FIG. 182.

A straight-edge, *AB*, is mounted on two trestles, and from it are suspended two plumb lines, *E* and *F*, as far apart as the breadth of the shaft will permit. To prevent agitation from currents of air, the bobs are permitted to dip into buckets of water, at the bottom of the shaft; the transit being at the *second* station, *K*, and the telescope turned in the direction of the first station, *D*, the straight-edge is moved by an assistant until both are seen in line from *K*; their plane then passes through the first course; and if the line *AB* be prolonged to *M* and *L*, the line *ML* will be directly over the first course, and consequently its bearing will be that of the first course. By measuring the line *E*, the depth of the shaft may be found.

395.—SECOND METHOD.

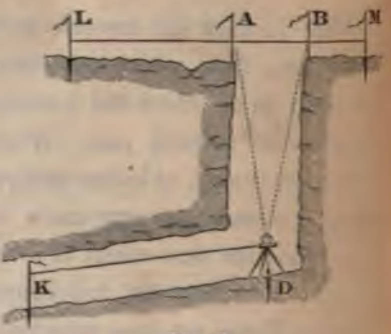


FIG. 183.

Let the transit, provided with a diagonal eye-piece, be planted over the station *D*, at the foot of the shaft, and after being leveled, let it be directed on the station *K*. Then, without changing the plane of vision, let the transit be directed to the top of the shaft, and let an assistant plant two flag rods, one at *A* and the other at *B*, both in the plane of vision, and let the line *AB* be prolonged to *L* and *M*, as before. The line *LM* will be in the same vertical plane with the first course, *DK*. Hence, as before, we may determine the bearing of the first course of the traverse.

396. Having, on the surface, the direction of the first course and the position of Station 1 of the traverse, Station 2 of the traverse may be found by laying off from Station 1, in the proper direction, a horizontal distance equal to the length of the first course. The position of Station 2 on the surface will thus be determined. Put the transit over the surface position of Station 2, make the zero of the vernier coincide with the zero of the horizontal limb and clamp the vernier plate; direct the telescope to surface Station 1 and clamp the limb; revolve the telescope on its horizontal axis, unclamp the vernier plate and revolve it around to the right, through the azimuth of the course, from 2 to 3; the line of sight of the telescope will then be in the direction of the traverse line from Station 2 to Station 3; measure from surface Station 2, in the direction found, a horizontal distance equal to the horizontal distance of the traverse line from Station 2 to Station 3; the extremity will be the surface position of Station 3. Clamp the vernier plate and remove the transit to surface Station 3; reverse the telescope on its horizontal axis, loosen the lower clamp and sight surface Station 2; tighten the lower clamp and revolve the telescope on its axis; unclamp the vernier plate and turn it through the azimuth of the course from 3 to 4; the line of sight of the telescope will then lie in the direction of the traverse line from Station 3 to Station 4; determine the surface position of Station 4 by measurement from surface Station 3, as before (see Art. **196**). Proceed, in like manner, to mark out on the surface the successive underground stations and courses, till the required point (9 in Fig. 181) is found.

397. The slope rod is a convenient instrument for use in making surface measurements.

A device for such a rod, for which caveat was entered by A. J. Rigby of New York in 1883, consists essentially, as shown in Fig. 184, of a horizontal bar 10 to 12 feet long, made to move up and down a vertical bar 6 to 8 feet long, to which it may be clamped in any position.

The horizontal bar, A, carries a scale, graduated to hundredths of a foot and reading by vernier to thousandths of a foot, a spirit level *E*, by which the bar may be made truly horizontal, and an extension bar *C*, which may be drawn out 4 to 6 making the extended bar 14 to 18 feet long; when the bar is drawn out, the reading is made by a vernier on the extension bar, as shown in the figure, in a manner similar to that in which the extended leveling rod is read (see Art. **290**). The vertical bar, *B*, also carries a graduated scale, reading by vernier to thousandths of a foot. The two clamp-screws, *FF*, working against a clamp-plate, fasten the horizontal to the vertical bar and keep it firmly in position, both horizontally and vertically, against its bearings on the vertical bar.

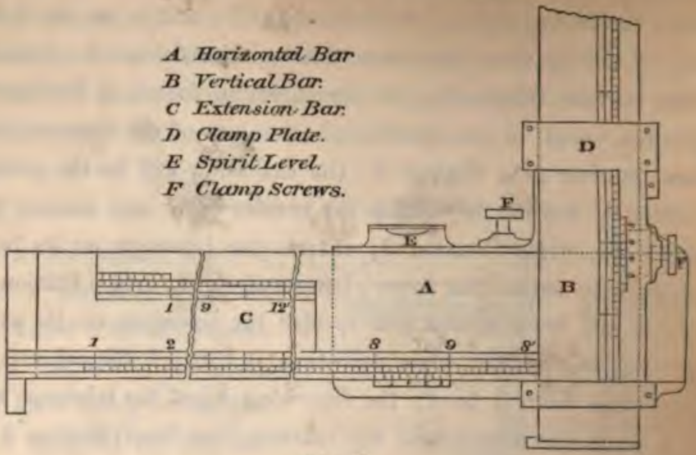


FIG. 184.

The manner of using the slope-rod is shown in Fig. 185. Pegs are driven into the ground at convenient stations along the line which is to be measured, the exact point on each being marked by the intersection of cross-lines on the top of the peg; if the selected station is on a rock, and a peg can not be driven, the cross-lines are marked in the rock to note the station. The front edge of the vertical bar is placed at the point marked on one peg and the end of the horizontal bar, extended if necessary, to the point marked on the other; the horizontal bar is moved slowly up and down the vertical bar till the bubble of the spirit-level E is in the middle of its run, and then clamped in position.

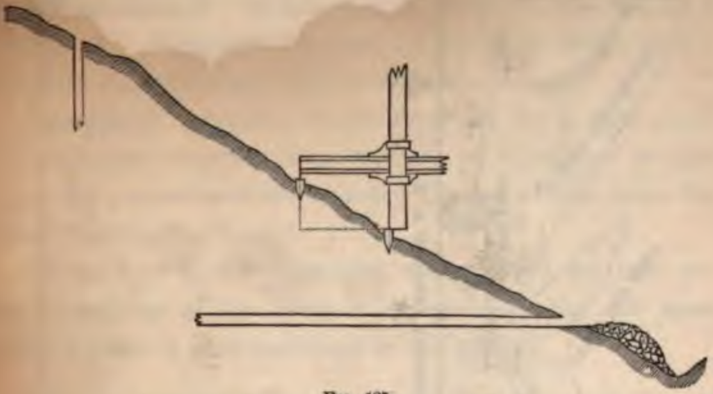


FIG. 185.

The reading on the horizontal bar will give the true horizontal distance between the two stations, and the reading on the vertical bar will give their difference of level.

398. A better method than repeating the traverse on the surface will appear from a consideration of the diagram, Fig. 181. It will be seen that the algebraic sums of the latitudes and departures respectively of the several courses, with respect to the first course taken as a meridian, are equal to the latitude and departure of the last or station 9. The latitude of 9 is the perpendicular of a right-angled triangle and the departure is the base; the distance AC, from 1 to 9, is equal to the square root of the sum of the squares of the latitude and departure of 9. The angle BAC may be found by the relation

$$\tan A = \frac{BC}{BA} \text{ (Art. } \mathbf{35}\text{).}$$

Having found the angle BAC, the bearing of AC, with respect to the course 1.2 taken as meridian, is equal to $90° - BAC$. Place the transit over station 1, level it, make the zero of the vernier coincide with the zero of the horizontal l

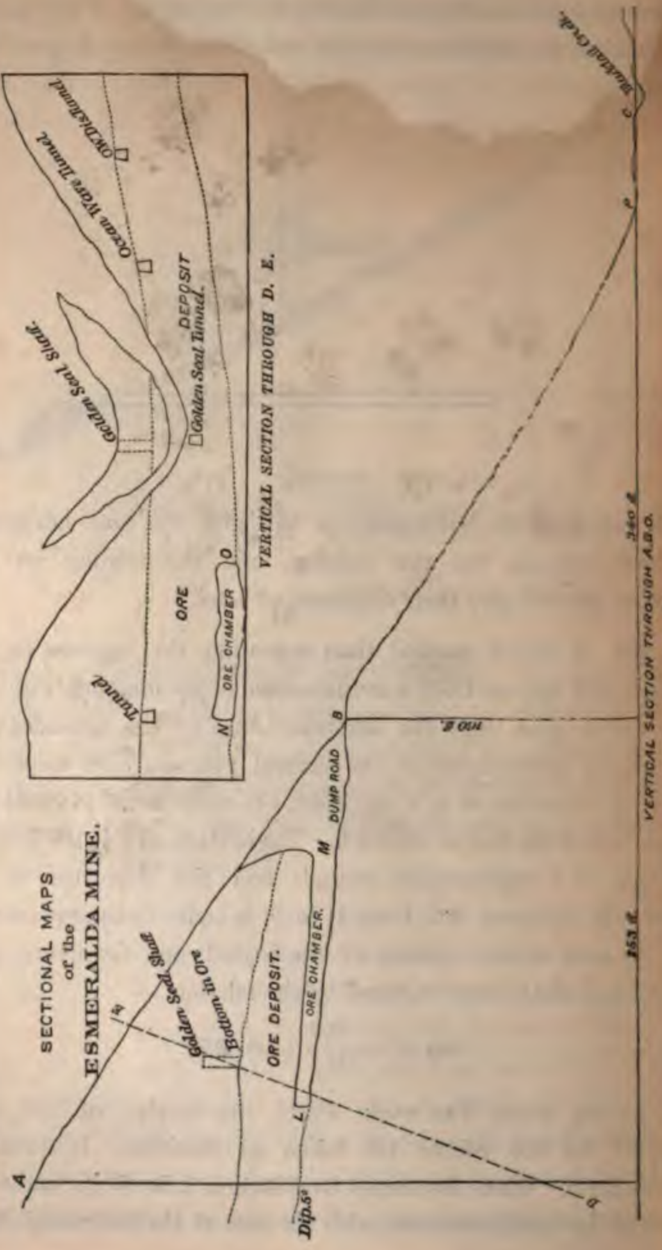

SECTIONAL MAPS
of the
ESMERALDA MINE.
A
E
Golden Seal Shaft
Bottom in Ore
ORE DEPOSIT.
ORE CHAMBER.
L
M
DUMP ROAD
B
Dip 5°
D
153 ft
100 ft
340 ft
P
C
Bullchill Creek.
VERTICAL SECTION THROUGH A.B.C.
Tunnel
ORE CHAMBER
N
O
ORE
Golden Seal Shaft.
DEPOSIT
Golden Seal Tunnel.
Ocean Wave Tunnel
O.K.Dist Tunnel
VERTICAL SECTION THROUGH D. E.

Fig. 18.

clamp the vernier plate, sight to station 2 and clamp the limb; unclamp the vernier plate, turn it through the bearing, as found, of *AC*, and clamp it; the line of sight of the telescope will be in the line *AC*. Measure the horizontal distance, as found, from *A* to *C*, and the point 9 will be accurately determined.

Again, from 1 measure off the departure of 9 at right angles to the assumed meridian, from the end of which, and at right angles to it, measure off the latitude; the end of this latter line will be the required point 9.

The surveyor should be satisfied with nothing less than perfect coincidence of the points so determined. Fig. 186 shows sectional maps of work performed in this manner.

399. To produce a line, previously marked out on the surface between two shafts, in the same relative direction below ground, so as to form a heading or tunnel from one shaft to another, proceed in the following manner:

Set up the transit at the bottom and in the centre of the shaft, as near as can be estimated by the eye, as at *a*, Fig. 187, and, after the instrument has been accurately leveled and the zero of the vernier made to coincide with the zero of the horizontal limb, sight up the shaft and make the cross-wires of the telescope bisect a mark *b*, in the line *AB* at the surface; revolve the telescope vertically a little until the vertical wire strikes the opposite side of the shaft at *c*. Measure the angle *cbe*, or its equal $\frac{cae}{2}$, and the radius of the shaft *ae*. The exact deviation of the centre of the transit from the vertical plane of the line *AB* at the surface, may then be found by calculation thus: Let the

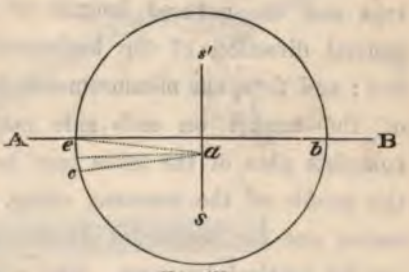


Fig. 187.

angular deviation, or angle *cae*, be 3° 10′, and the radius of the shaft 60 inches, then

$$\sin\frac{cae}{2} \times ae = .27639 \times 60 = 16.5,$$

the deviation required in inches. Remove the transit from *a* along the line *ss′*, and toward *s′*, a distance of 16.5 inches; it will then occupy its true position, or be in the same vertical plane as the line *AB* at the surface.

The transit may now be adjusted and leveled, and the telescope pointed up the shaft; when, if the preceding operation has been properly performed, the vertical wire will exactly pass through the marks previously fixed at *e* and *b* (H. D. Hoskold). Revolving the telescope down, its line of sight will give the true direction below ground of the line *AB* at surface.

Method of Plotting the Traverse on Paper.

400. To plot the traverse on paper, we first plot the plan by the usual method of plotting compass-work, using the bearings and the reduced lengths of the courses. This gives the general direction of the horizontal projection of the traverse run; and from the measurements for cross-section, the breadths of the tunnel on each side may be plotted, and thence a complete *plan* of the mine may be constructed. We next plot the profile of the traverse, using, as in railroad plotting, two scales, one for horizontal distances, and the other and larger one for vertical distances. The relation between the two scales will depend upon the circumstances of the case. Sometimes, both may be equal. The profile represents the undulation of the traverse, without reference to its horizontal deviations. Let us conceive vertical planes to be passed through all the courses. These will intersect each other in vertical lines. Take the one through the first course, as the one on which the profile is to be delineated. Then, beginning with the plane through the last course, conceive the other planes to be revolved, in order, each about its intersection with the preceding one, to coincide with it, and so on till all are brought into coincidence with the fixed one. The lines of the traverse will then be situated in one plane, and a plot of them, in this position, will be the profile required. The distances from the traverse to the floor and roof of the tunnel, at different points, enable us to complete the profile.

SECTION IV.

PRACTICAL APPLICATIONS.

401. To determine the position and depth of a mine shaft, *CB*, Fig. 188, which is to connect with a tunnel *AB*.

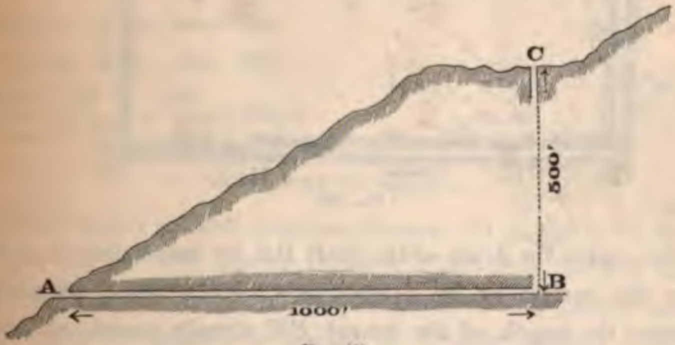


FIG. 188.

If the course of the tunnel is not a straight line it must be traversed. Assuming it to be a straight line, the bearing is obtained with the transit. The length of the tunnel is then accurately measured with a steel tape or a rod. The surveyor now stakes out the course on the surface, then beginning at the mouth of the tunnel the first peg is driven on a level with the floor, and the measurement of the tunnel, say 1000 feet, is laid off on the course established on the surface. If the slope rod is used, the sum of the vertical measurements or readings will be the vertical distance of *C* above *A*. Should the tunnel at *B* be higher or lower than at *A*, the difference subtracted from or added to the sum of the vertical readings, will be the required depth of the shaft. If the slope-rod is not used, a line of levels must be run to find the difference of level between *A* and *C*.

402. To find the distance necessary to connect the main shaft *GF* and the tunnel *EF* (Fig. 189).

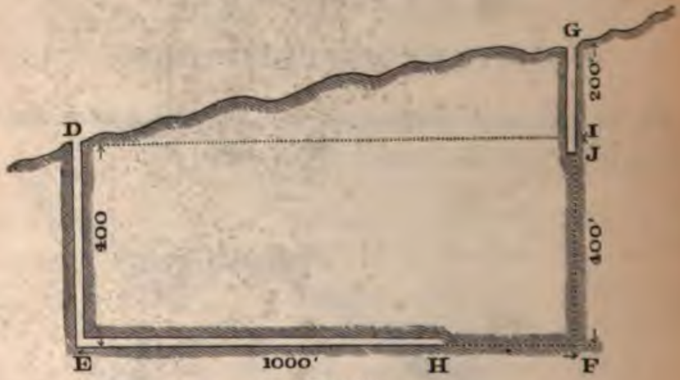


Fig. 189.

Determine the depth of the shaft *DE*, by suspending a chain from the surface or by a steel tape with a weight attached. Measure the length of the tunnel *EH*, already completed, and, with the slope rod, or otherwise, obtain the horizontal distance *DI*, and the difference of level between the points *D* and *G*. This difference of level added to the depth of the shaft $DE =$ the total depth of the shaft *GF*. Find the depth of the shaft *GJ* already completed. Then $GF - GJ = JF$, and $EF - EH = HF$, the required distances. In this case the tunnel is assumed to be traight and the position of the shaft determined as in the preceding problem.

403. To find the depth of a mine shaft AB, Fig. 190, the distance from the outcrop at C and the dip of the vein CB being given.

Determine the difference of level $AD = 100$ ft.

The horizontal distance $CD = 600$ ft.

Angle $DCB = 60°$.

Then $DB = CD \tan 60° = 1039.2$ ft.

And $AB = AD + DB = 100 + 1039.2 = 1139.2$.

To find the distance from the outcrop to the point of intersection, or the distance CB, we have (Davies' Leg., Trig., Art. **37**),

$$CB = \frac{CD}{\cos 60^\circ} = \frac{600}{\frac{1}{2}} = 1200.$$

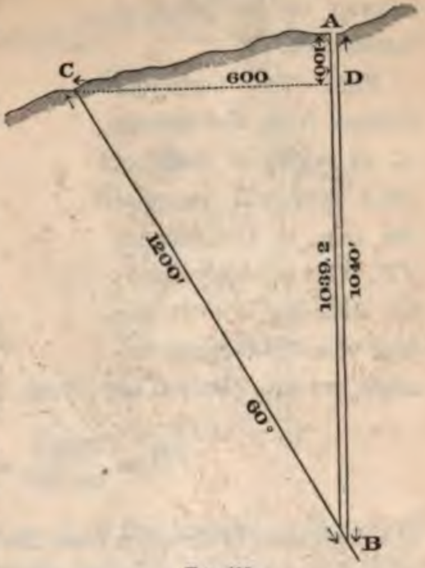


FIG. 190.

BY CONSTRUCTION.

Draw to any suitable scale the distance $CD = 600$ feet; from C draw the line CD, making an angle of 60° with the line CD; from the point D draw a line perpendicular to CD, until it intersects CB at B; produce it upward to A, until distance from D to A = difference of elevation between C and A. Measure the line AB on the scale, which gives the required depth. Measure also CB on the scale, which is the distance from the outcrop to the point of intersection.

404. Given the depth of the shaft $DE = 588.5$ feet, Fig. 191, and the horizontal distance FD from the outcrop to th of shaft = 500 feet, and the angle $GFD = 60°$, to find the length of a cross-cut EG from the bottom of the shaft to intersect the vein; also the distance from the outcrop to the point of intersection.

Find the horizontal distance from the outcrop F, at which a shaft of 588.5 feet will intersect the vein, or the distance FH. This is readily found; for assuming it to be the base of a right-angled triangle, we have (Davies' Leg., Trig., Art. **37**),

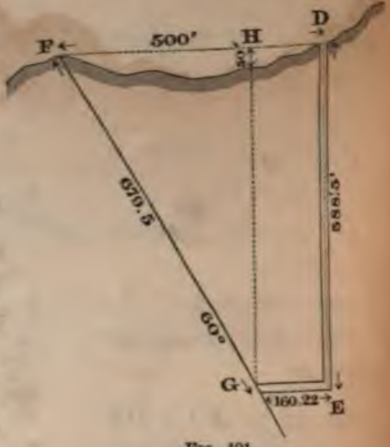


FIG. 191.

$$FH = \frac{588.5}{\tan 60°} = 339.78.$$

If a depression or elevation from the outcrop occurs at the point, it must be subtracted from or added to the depth of the shaft; for example, if there is a depression of 50 ft. it will only be necessary to sink 538.5 ft. to the point of intersection. The horizontal distance so found, subtracted from the real distance of the shaft from the outcrop = length of cross-cut = 160.22, and

$$FG = \sqrt{DE^2 + (FD - GE)^2} = 679.5.$$

BY CONSTRUCTION.

Draw the line $FD = 500$ feet to any convenient scale. From F draw the line FG, making the angle $DFG = 60°$. Draw $DE = 588.5$ ft., and from E draw EG parallel to FD. The distances can now be taken from the scale.

405. Given the angle $LJK = 60°$. The distance $JL = 700$ ft., and the difference of level between J and $H = 100$ ft. Required the depth of a shaft from H that will intersect a cross-cut of 350 ft. from the point K, Fig. 192.

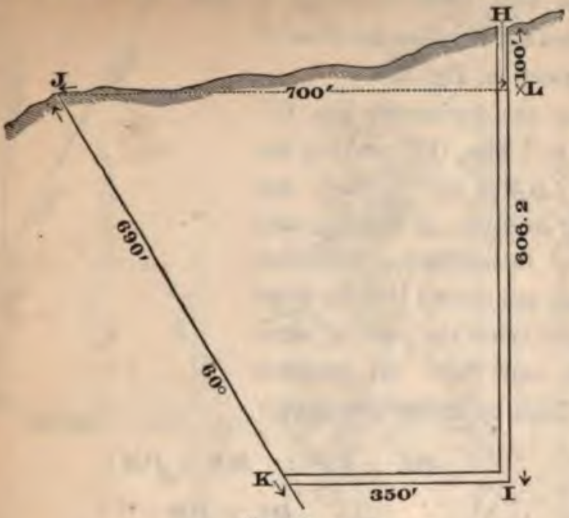


FIG. 192.

From the point K draw to JL a line parallel to HI; it will intersect JL $700 - 350 = 350$ ft. from the point J. This line is the perpendicular of a right-angled triangle, and we have it $= 350 \tan 60°$. Add to this the difference of elevation, which is the required depth.

BY CONSTRUCTION.

Draw the line $JL = 700$ ft., and from J draw JK, making the angle $LJK = 60°$. From K set off the distance KI, parallel to JL, and make it 350 ft. From I raise the perpendicular IL and extend it to H, making the distance $LH = 100$ ft. of the scale. The distance IH is now taken from the scale.

Problems of this kind occur only where there are inclined shafts.

406. Given the distance $OL = 400$ ft., and the angle $LON = 60°$; to find the depth of a shaft at the point of intersection with the vein, and to find the length of a cross-cut that will again intersect the vein when the shaft is continued 250 ft. below the point of its intersection, Fig. 193.

Draw the horizontal line $OL = 400$ ft. Also ON, making the angle $LON = 60°$. Then 400 tan 60° = depth of shaft at the point of intersection. Construct the shaft and extend it to the point M, 250 ft. below the point of intersection, and draw the cross-cut MN. Then by similar triangles,

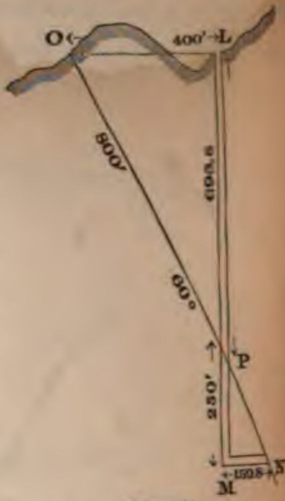


Fig. 193.

$$OL : LP :: MN : PM;$$

$$\therefore \quad MN = \frac{OL \times PM}{LP}.$$

BY CONSTRUCTION.

Draw $OL = 400$ ft.; also ON, making the angle $LON = 60°$; and LM to the point M, 250 ft. below the point of intersection P. From the scale take off LP and MN the required distances.

In the preceding problems the angle of 60° was employed for convenience of construction, but the principles would be true for any other angle.

407. Figures 194, 195, 196, represent plan, longitudinal and transverse sections of a developed mine.

The development consists of a vertical shaft, an inclined wing the dip of the vein, and 6 one-hundred-foot

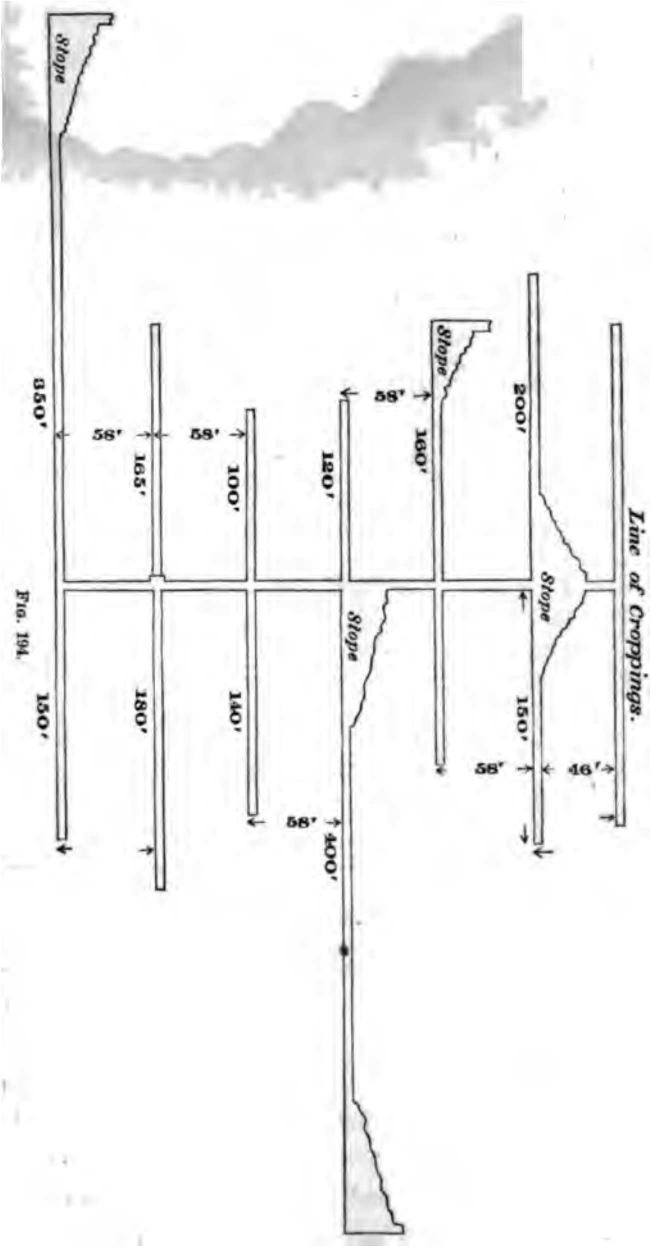

Line of Croppings.
Slope
Slope
Slope
Slope

FIG. 194.

In opening mines it is considered good practice to follow the vein for a considerable distance in depth, to be fully satisfied of its continuity, before sinking a vertical shaft for deep working.

Should the vein be vertical, however, the prospecting shaft may be made the working shaft. The depth to which a shaft is sunk on the dip of the vein will depend upon the Engineer in

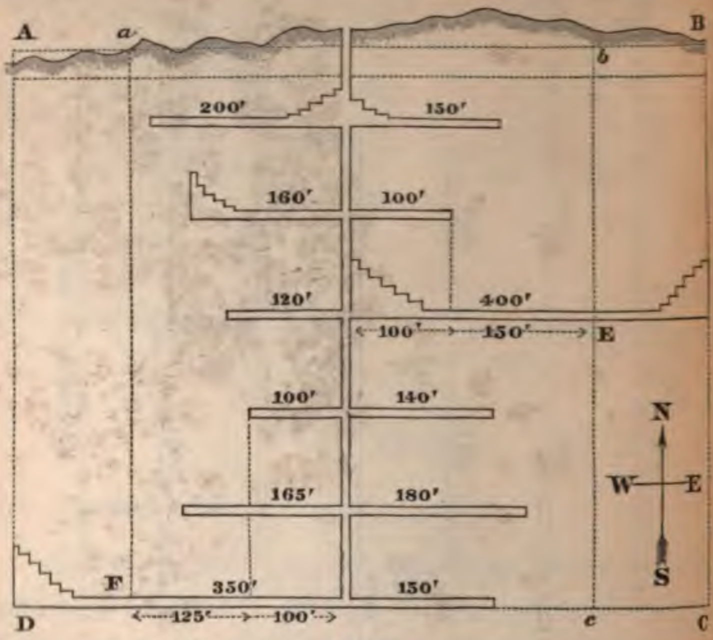


Fig. 195.

charge and upon the characteristics of the vein. A careful engineer will not incur the expense of sinking a deep working shaft to intersect an inclined vein, until he has followed the vein for such a distance that the possibility of its terminating, or "pinching out," is quite remote. Should the vein be irregular and not possess well-defined fissure characteristics, the greater the necessity for care in this respect and, in cases of great uncertainty, it would even be advisable to have the working shaft follow the dip

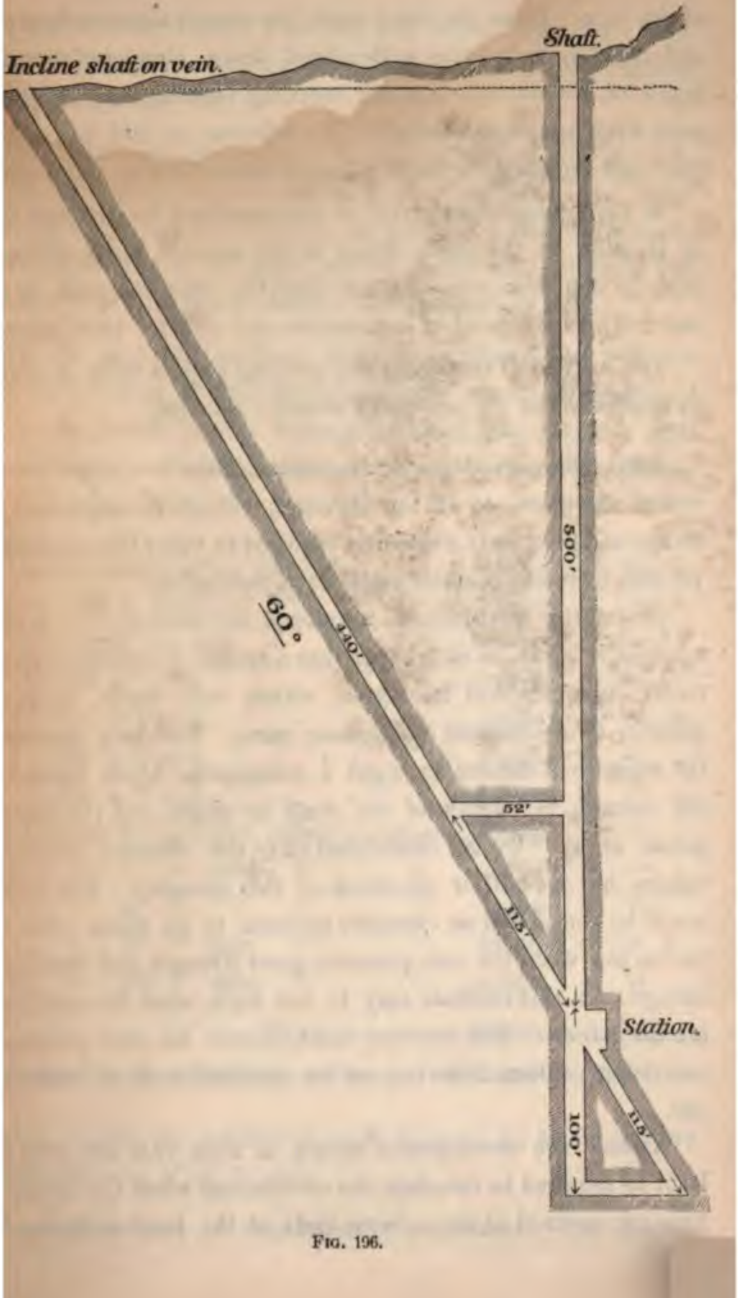


FIG. 196.

of the vein. If, on the other hand, the vein is found to be strong and regular, possessing well-defined fissure characteristics to a depth of 150 to 250 feet, the working vertical shaft might be sunk with comparative safety. No rule can be laid down, however, and the Engineer must always exercise his own judgment.

In the example here given, we have assumed the inclined shaft to be sunk to the same depth as the vertical, for if originally sunk to the first cross-cut, 440 feet (Fig. 196), it would be carried down to the point of intersection and used for ventilation.

The method of surveying and plotting such a mine is simply an application of the principles already explained.

408. The calculation of ore-reserves does not come strictly within the province of the surveyor, yet after completing the survey and plot, he is frequently required to make the calculation. We will therefore consider methods of making it.

In practice the methods employed are various. No general rule can be given, as each expert has a system of his own, and different engineers will not agree, within wide limits, as to the quantity of ore-reserves in the same mine. One may assume as the measure of the ore in sight a rectangular block limited by the outcrop, the depth of the shaft or shafts, and the extreme points of the levels, diminished by the amount extracted. Others, but one-half or one-third of this quantity. The former would be considered an excessive estimate in all cases. The latter too low when the vein possesses great strength and regularity, though even this estimate may be too high, when the conditions are the reverse. The surveyor must exercise his own judgment, exercising caution, however, as the calculation is an important one.

Assume the development shown in Figs. 194, 195, 196, and let it be required to calculate the ore-reserves when the bounding lines are assumed at the extreme ends of the level drifts, or the rectangular block *ABCD*, Fig. 195, and when the average cross-section of the vein is 6 feet, and a cubic foot of the vein matter in place weighs 150 lbs.

Ore stopes, or *steps* made in mine-workings by and for the extraction of ore, are generally very irregular, the representation here being an ideal one. Suppose the stope-faces to be 11 feet apart and 8 feet high, and that the inclined shaft has extracted 10 × 6 ft. of vein matter, and the levels 7 × 6 ft.

We see that the inclined shaft has exposed the vein for 440 + 115 + 115 = 670 ft.; deducting say 15 ft. for inequality of surface, we should have a rectangular block 655 × (400 + 350) × 6 in width = 2947500 cubic feet of ore: to be deducted from this, we have

The inclined shaft 655 × 10 × 6	= 39300	cubic feet.
1st level (150 + 200) × 7 × 6	= 14700	" "
2d " 260 × 7 × 6	= 10920	" "
3d " 520 × 7 × 6	= 21840	" "
4th " 240 × 7 × 6	= 10080	" "
5th " 345 × 7 × 6	= 14490	" "
6th " 500 × 7 × 6	= 21000	" "
Stoped out on 1st level east, roughly estimated,	3400	" "
" " " " west " "	6500	" "
" " 2d " " " "	7000	" "
" " 3d " east " "	20000	" "
" " 6th " west " "	12000	" "
Total,	182000	cu. ft. (say).
Deducting this from 2947500, we have,	2765500	" "

Dividing by 13½, the number of cu. ft. required for a ton, and we have 204852 tons of ore in sight.

Another method of calculation is as follows: The longest drift east is 400 ft. and the shortest 100 ft. Assume the bounding line in this direction to be at a distance east of the shaft,

$$100 + \frac{400 - 100}{2} = 250 \text{ ft.}$$

The longest drift west is 350 ft. and the shortest 100 ft.; take the bounding line in this direction at a distance

$$100 + \frac{350 - 100}{2} = 225 \text{ ft.},$$

or the rectangular block *abcF*, Fig. 195. Calculate the ore-reserves, when the other data are the same as before.

This latter method is recommended by competent engineers as the fairest and most reliable for all parties concerned.

409. Fig. 197 shows a longitudinal section, and Fig. 198 a transverse section of a deposit mine with mill connections, the mill to be erected at the point A. From a consideration of the diagram, it is evident that the most convenient method for the transportation of the ore from the mine to the mill would be by a tunnel driven into the mountain, at the end of which is a bin, made in the solid rock and inclined to the tunnel at any convenient angle at which ore will slide into cars; the cars to be run into the tunnel on a track and directly under iron doors which are worked by rack and pinion. The bin is to connect with the ore-chamber by a chute inclined at an angle of 45°, as shown in the diagram.

The lower or mill tunnel should have a slope of 2 inches in 10 feet, so that the loaded cars would descend by the force of gravity, the last car in a train having a brake with which to regulate the speed. The chute should be 12 to 15 feet from the edge of the tunnel, to admit of constructing the inclined bin for the discharge of the ore into the cars. The point in the ore-chamber, at which it is desired to sink the chute, and the mouth of the lower tunnel being selected, drive a peg to the centre point

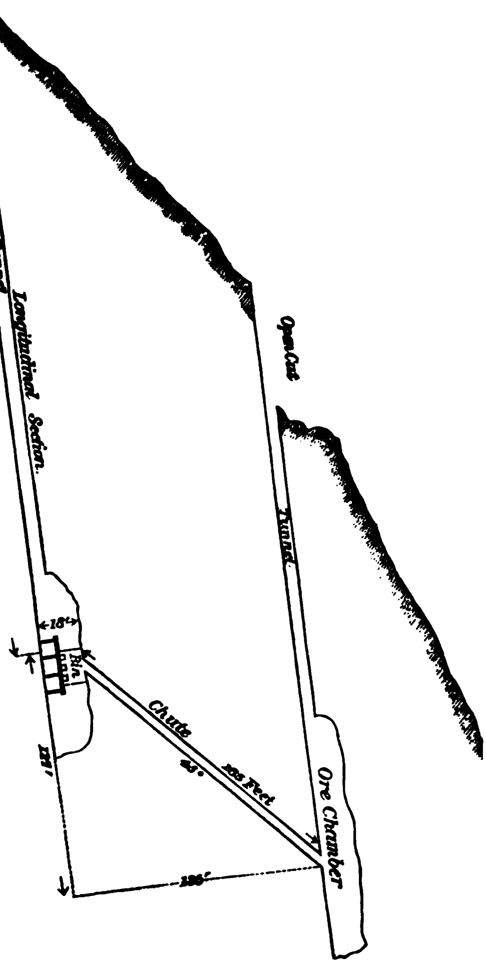


FIG. 197.

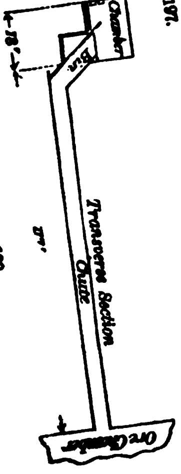


FIG. 198.

of the proposed tunnel floor and drive a nail in the peg, and repeat the operation at the point where the chute is to be sunk. Now make a careful traverse between these points; the direction of a line which will run from the mouth of the tunnel directly under the point selected for the chute can now be found, as explained in the section on traversing, and the course that will carry the tunnel 12 or 15 feet from the bottom of the chute may be determined. In driving the tunnel, holes should be drilled in the roof and wooden spuds driven in on which to hang plumb-bobs, the surveyor using great care to have the plumb-bobs suspended in the proper course as a guide to the miners. In starting the chute, a large wooden triangle should be made, one of the angles of which is the same as the angle of the chute, to be used by the miners as a guide, until sufficient depth is attained to hang, in the proper line, plumb-bobs, the points of which are on the required angle.

APPENDIX A.

THE SOLAR COMPASS.

(With some omissions, from Messrs. W. and L. E. Gurley's Manual of Engineering and Surveying Instruments, 24th Edition, 1883.)

This instrument, so ingeniously contrived for readily determining a true meridian or north and south line, was invented by William A. Burt, of Michigan, and patented by him in 1836.

It has since come into general use in the surveys of U. S. public lands, the principal lines of which are required to be run with reference to the true meridian.

The arrangement of its sockets and plates is similar to that of the Surveyors' Transit, except that the sight vanes are attached to the under plate or limb, and this revolves around the upper or vernier plate on which the solar apparatus is placed.

The limb is divided to half degrees, is figured in two rows, and reads by the two opposite verniers to single minutes.

The Solar Apparatus.—The Solar Apparatus is seen, Fig. 1, in the place of the needle, and in fact operates as its substitute in the field.

It consists mainly of three arcs of circles, by which can be set off the latitude of a place, the declination of the sun, and the hour of the day.

These arcs, designated in the cut by the letters *a*, *b*, and *c*, are therefore termed the latitude, the declination, and the hour arcs respectively.

The Latitude Arc, *a*, has its centre of motion in two pivots, one of which is seen at *d*, the other is concealed in the cut.

It is moved either up or down within a hollow arc, seen in the cut, by a tangent screw at *f*, and is securely fastened in any position by a clamp screw.

The Latitude arc is graduated to quarter degrees, and reads by its vernier, *e*, to single minutes; it has a range of about thirty-five degrees, so as to be adjustable to the latitude of any place in the United States.

The Declination Arc, *b*, is also graduated to quarter degrees, and has a range of about twenty-eight degrees.

Its vernier, *v*, reading to single minutes, is fixed to a movable arm, *h*, having its centre of motion at the end of the declination arc at *g*; the arm is moved over the surface of the declination arc, and its vernier set to any reading by turning the head of the tangent screw *k*. It is also securely clamped in any position by a screw, concealed in the engraving.

Solar Lenses and Lines.—At each end of the arm, *h*, is a rectangular block of brass, in which is set a small convex lens, having its focus surface of a little silver plate A, Fig. 2, fastened by screws to the inside of the opposite block.

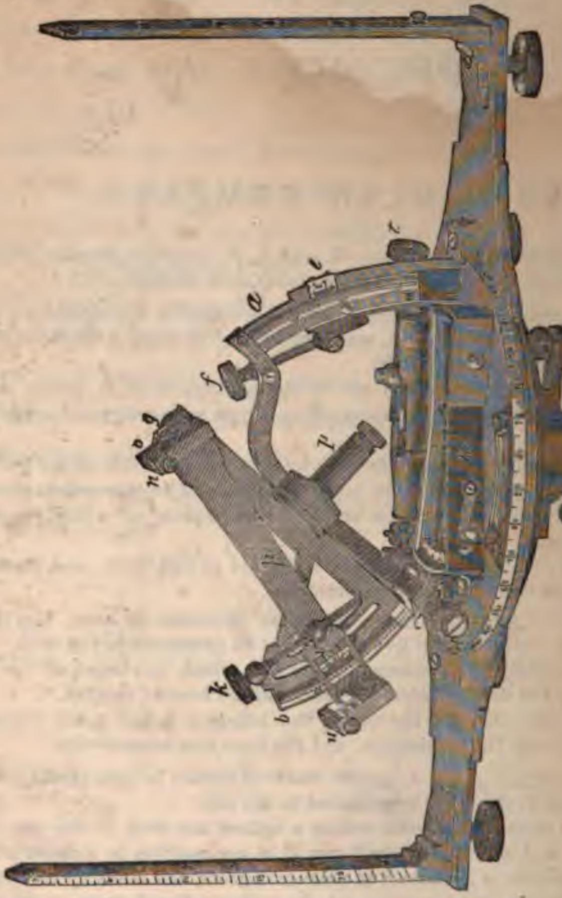


Fig. 1.

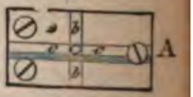


Fig. 2.

On the surface of the plate are marked two sets of lines intersecting each other at right angles; of these *b b* are termed the hour lines, and *c c* the equatorial lines, as having reference respectively to the hour of the day and the position of the sun in relation to the equator.

In Fig. 1 the equatorial lines are those on the lower block, parallel to the surface of the hour arc *c*; the hour lines are of course those at right angles to the first.

Equatorial Sights.—On the top of each of the rectangular blocks is seen a little sighting-piece, termed the equatorial sight, fastened to the block by a small milled head-screw, so as to be detached at pleasure.

They are used, as will be explained hereafter, in adjusting the different parts of the solar apparatus.

The Hour Arc, *c*, is supported by the two pivots of the latitude arc already spoken of, and is also connected with that arc by a curved arm, as shown in the figure.

The hour arc has a range of about 120°, is divided to half degrees, and figured in two series; designating both the hours and the degrees, the middle division being marked 12 and 90 on either side of the graduated lines.

The Polar Axis.—Through the centre of the hour arc passes a hollow socket, *p*, containing the spindle of the declination arc, by means of which this arc can be moved from side to side over the surface of the hour arc, or turned completely round, as may be required.

The hour arc is read by the lower edge of the graduated side of the declination arc.

The axis of the declination arc, or indeed the whole socket *p*, is appropriately termed the polar axis.

The Adjuster.—Besides the parts shown in the cut, there is also an arm used in the adjustment of the instrument as described hereafter, but laid aside in the box when that is effected.

The parts just described constitute properly the solar apparatus.

Besides these, however, are seen the needle-box, *n*, with its arc and tangent screw, *t*, and the spirit levels, for bringing the whole instrument to a horizontal position.

The Needle-Box, *n*, has an arc of about 36° in extent, divided to half degrees, and figured from the centre or zero mark on either side.

The needle is raised or lowered by a lever shown in the cut.

The needle-box is attached by a projecting arm to a tangent-screw, *t*, by which it is moved about its centre, and its needle set to any variation.

This variation is also read off by the vernier on the end of the projecting arm, reading to three minutes a graduated arc, attached to the plate of the compass.

The Levels seen with the solar apparatus have ground glass vials, and are adjustable at their ends like those of other instruments.

The edge of the circular plate on which the solar work is placed, is divided and figured at intervals of ten degrees, and numbered, as shown, from 0 to 90 on each side of the line of sight.

These graduations are used in connection with a little brass pin, seen in the centre of the plate, to obtain approximate bearings of lines, which are not important enough to require a close observation.

Lines of Refraction —The inside faces of the sights are also graduated and figured, to indicate the amount of refraction to be allowed when the sun is near the horizon. These are not shown in the cut.

Principles of the Solar Compass.—The interval between two equatorial lines *c c*, in Fig. 2, as well as between the hour lines *b b*, is just sufficient to include the circular image of the sun as formed by the solar lens on the opposite end of the revolving arm *h*, Fig. 1.

When, therefore, the instrument is made perfectly horizontal, the torial lines and the opposite lenses being accurately adjusted to each other by a previous operation, and the sun's image brought within the equatorial lines, his position in the heavens, with reference to the horizon, will be defined with precision.

Suppose the observation to be made at the time of one of the equinoxes; the arm h, set at zero on the declination arc b, and the polar axis p placed exactly parallel to the axis of the earth.

Then the motion of the arm h, if revolved on the spindle of the declination arc around the hour circle c, will exactly correspond with the motion of the sun in the heavens, on the given day and at the place of observation; so that if the sun's image was brought between the lines c c, in the morning, it would continue in the same position, passing neither above nor below the lines, as the arm was made to revolve in imitation of the motion of the sun about the earth.

In the morning, as the sun rises from the horizon, the arm h will be in a position nearly at right angles to that shown in the cut, the lens being turned towards the sun, and the silver plate on which his image is thrown directly opposite.

As the sun ascends, the arm must be moved around, until, when he has reached the meridian, the graduated side of the declination arc will indicate 12 on the hour circle, and the arm h, the declination arc b, and the latitude arc a, will be in the same plane.

As the sun declines from the meridian the arm h must be moved in the same direction, until at sunset its position will be the exact reverse of that it occupied in the morning.

Allowance for Declination.—Let us now suppose the observation made when the sun has passed the equinoctial point, and when his position is affected by declination.

By referring to the Almanac, and setting off on the arc his declination for the given day and hour, we are still able to determine his position with the same certainty as if he remained on the equator.

When the sun's declination is south, that is, from the 22d of September to the 20th of March in each year, the arc b is turned toward the plates of the compass, as shown in the engraving, and the solar lens, o, with the silver plate opposite, are made use of in the surveys.

The remainder of the year, the arc is turned from the plates, and the other lens and plate employed.

When the Solar Compass is accurately adjusted, and its plates made perfectly horizontal, the latitude of the place, and the declination of the sun for the given day and hour, being also set off on the respective arcs, *the image of the sun cannot be brought between the equatorial lines until the polar axis is placed in the plane of the meridian of the place, or in a position parallel to the axis of the earth.* The slightest deviation from this position will cause the image to pass above or below the lines, and thus discover the error.

We thus, from the position of the sun in the solar system, obtain a certain direction absolutely unchangeable, from which to run our lines, and measure the horizontal angles required.

This simple principle is not only the basis of the construction of the Solar Compass, but the sole cause of its superiority to the ordinary or magnetic instrument. For in a needle instrument the accuracy of the horizontal angles indicated, and therefore of all the observations made, depends upon "the delicacy of the needle, and the constancy with which it assumes a certain direction, termed the magnetic meridian."

The principal causes of error in the needle, briefly stated, are the dulling of the pivot, the loss of polarity in the needle, the influence of local attraction, and the effect of the sun's rays, producing the diurnal variation.

From all these imperfections the solar instrument is free.

The sights and the graduated limb being adjusted to the solar apparatus, and the latitude of the place and the declination of the sun also set off upon the respective arcs, we are able not only to run the true meridian, or a due east and west course, but also to set off the horizontal angles with minuteness and accuracy from a direction which never changes, and is unaffected by attraction of any kind.

To Adjust the Solar Compass.—The adjustments of this instrument, with which the surveyor will have to do, are few in number, and will now be given in order.

1st. **To Adjust the Levels.**—Proceed precisely as directed in the account of the other instruments described, by bringing the bubbles into the centre of the tubes by the leveling screws of the tripod, and then reversing the instrument upon its spindle, and raising or lowering the ends of the tubes until the bubbles will remain in the centre during a complete revolution of the instrument.

2d. **To Adjust the Equatorial Lines and Solar Lenses.**—First detach the arm *h* from the declination arc by withdrawing the screws shown in the cut from the ends of the posts of the tangent-screw *k*, and also the clamp-screw, and the conical pivot with its small screws by which the arm and declination arc are connected.

The arm *h* being thus removed, attach the adjuster in its place by replacing the conical pivot and screws, and insert the clamp-screw so as to clamp the adjuster at any point on the declination arc.

Now level the instrument, place the arm *h* on the adjuster, with the same side resting against the surface of the declination arc as before it was detached. Turn the instrument on its spindle so as to bring the solar lens to be adjusted in the direction of the sun, and raise or lower the adjuster on the declination arc, until it can be clamped in such a position as to bring the sun's image as near as may be between the equatorial lines on the opposite silver plate, and bring the image precisely into position by the tangent of the latitude arc or the leveling-screws of the tripod. Then carefully turn the arm half way over, until it rests upon the adjuster by the opposite faces of the rectangular blocks, and again observe the position of the sun's image.

If it remains between the lines as before, the lens and plate are in adjustment; if not, loosen the three screws which confine the plate to the block, and move the plate under their heads, until one-half the error in the position of the sun's image is removed.

Again bring the image between the lines, and repeat the operation until it will remain in the same situation, in both positions of the arm, when the adjustment will be completed.

To adjust the other lens and plate, reverse the arm end for en juster, and proceed precisely as in the former case, until the same result is attained.

In tightening the screws over the silver plate, care must be taken not to move the plate.

This adjustment now being complete, the adjuster should be removed, and the arm *h*, with its attachments, replaced as before.

3d. To Adjust the Vernier of the Declination Arc.—Having leveled the instrument, and turned its lens in the direction of the sun, clamp to the spindle, and set the vernier *v*, of the declination arc, at zero, by means of the tangent-screw at *k*, and clamp to the arc.

See that the spindle moves easily and yet truly in the socket, or polar axis, and raise or lower the latitude arc by turning the tangent-screw *f*, until the sun's image is brought between the equatorial lines on one of the plates. Clamp the latitude arc by the screw, and bring the image precisely into position by the leveling-screws of the tripod or socket, and without disturbing the instrument, carefully revolve the arm *h*, until the opposite lens and plate are brought in the direction of the sun, and note if the sun's image comes between the lines as before.

If it does, there is no index error of the declination arc; if not, with the tangent-screw *k*, move the arm until the sun's image passes over half the error; again bring the image between the lines, and repeat the operation as before, until the image will occupy the same position on both the plates.

We shall now find, however, that the zero marks on the arc and the vernier do not correspond, and to remedy this error, the little flat-head screws above the vernier must be loosened until it can be moved so as to make the zeros coincide, when the operation will be completed.

4th. To Adjust the Solar Apparatus to the Compass Sights.—First, level the instrument, and with the clamp and tangent-screws set the main plate at 90° by the verniers and horizontal limb. Then remove the clamp-screw, and raise the latitude arc until the polar axis is by estimation very nearly horizontal, and if necessary, tighten the screws on the pivots of the arc, so as to retain it in this position.

Fix the vernier of the declination arc at zero, and direct the equatorial sights to some distant and well-marked object, and observe the same through the compass sights. If the same object is seen through both, and the verniers read to 90° on the limb, the adjustment is complete; if not, the correction must be made by moving the sights or changing the position of the verniers.

It should be remarked that as the solar work is attached permanently to the sockets, and this adjustment is made by the maker, it will need no further attention at the hands of the surveyor except in case of serious accidents.

The other adjustments are of course also made in the process of finishing the instrument, and are liable to very little derangement in the ordinary use of the Solar Compass.

To Use the Solar Compass.—Before this instrument can be used at any given place, it is necessary to set off upon its arcs both the declination [illegible] as affected by its refraction for the given day and hour, and the [illegible] place where the observation is made.

To Set Off the Declination.—The declination of the sun, given in the ephemeris of the Nautical Almanac from year to year, is calculated for apparent noon at Greenwich, England.

To determine it for any other hour at a place in the U. S., reference must be had, not only to the difference of time arising from the longitude, but also to the change of declination from day to day.

The longitude of the place, and therefore its difference in time, if not given directly in the tables of the Almanac, can be ascertained very nearly by reference to that of other places given, which are situated on, or very nearly on, the same meridian.

It is the practice of surveyors in the States east of the Mississippi to allow a difference of *six* hours for the difference in longitude, calling the declination given in the Almanac for 12 M., that of 6 A. M., at the place of observation.

Beyond the meridian of Santa Fe, the allowance would be about *seven* hours, and in California, Oregon, and Washington Territory about *eight* hours.

Having thus the difference of time, we very readily obtain the declination for a certain hour in the morning, which would be earlier or later as the longitude was greater or less, and the same as that of apparent noon at Greenwich on the given day. Thus, suppose the observation made at a place, say, five hours later than Greenwich, then the declination given in the Almanac for the given day at noon, affected by the refraction, would be the declination at the place of observation for 7 o'clock A. M.; this gives us the starting-point.

To obtain the declination for the other hours of the day, take from the Almanac the declination for apparent noon of the given day, and, as the declination is increasing or decreasing, add to or subtract from the declination of the first hour the difference for one hour as given in the ephemeris, which will give, when affected by the refraction, the declination for the succeeding hour; and proceed thus in making a table of the declination for every hour of the day.

To Set Off the Latitude.—Find the declination of the sun for the given day at noon, at the place of observation as just described, and with the tangent-screw set it off upon the declination arc, and clamp the arm firmly to the arc.

Observe in the Almanac the equation of time for the given day, in order to know about the time the sun will reach the meridian.

Then, about fifteen or twenty minutes before this time, set up the instrument, level it carefully, fix the divided surface of the declination arc at 12 on the hour circle, and turn the instrument upon its spindle until the solar lens is brought into the direction of the sun.

Loosen the clamp-screw of the latitude arc, and with the tangent-screw raise or lower this arc until the image of the sun is brought precisely between the equatorial lines, and turn the instrument from time to time so as to keep the image also between the hour lines on the plate.

As the sun ascends, its image will move below the lines, and the arc must be moved to follow it. Continue thus, keeping it between the two sets of lines until its image begins to pass above the equatorial lines, which is also the moment of its passing the meridian.

Now read off the vernier of the arc, and we have the latitude half an hour of the horizon, nor at noon, for about the same interval, before and after it passes the meridian.

Allowance for Refraction.—The proper allowance to be made for refraction in setting off the declination of the sun upon the Solar Compass has long been a source of perplexity to the surveyor; we have, accordingly, given the subject a good deal of attention, and here publish a table, by which the amount of refraction for any hour of any day of the year can be ascertained, and set off with a degree of accuracy which is all that can be desired.

A TABLE OF MEAN REFRACTIONS IN DECLINATION.

To apply on the declination arc of Solar Attachment of either Compasses or Transits.

Computed by EDWARD W. ARMS, C. E., for W. & L. E. GURLEY, Troy, N. Y.

HOUR ANGLE	DECLINATIONS.								
	For Latitude 30°.								
	+ 20°	+ 15°	+ 10°	+ 5°	0°	— 5°	—10°	—15°	—20°
0h.	10″	15″	21″	27″	33″	40″	48″	57″	1′08″
2	14	19	25	31	38	46	54	1′05	1 18
3	20	26	32	39	47	55	1′06	1 19	1 36
4	32	39	46	52	1′06	1′19	1 35	1 57	2 29
5	1′00	1′10	1′24	1′52	2 07	2 44	3 46	5 43	13 06
	For Latitude 32° 30′.								
0h.	13″	18″	24″	30″	36″	44″	52″	1′02″	1′14″
2	17	22	28	35	42	50	1′00	1 11	1 26
3	23	29	35	43	51	1′01	1 13	1 28	1 47
4	35	43	51	1′01	1′13	1 27	1 46	2 13	2 54
5	1′03	1′15	1′31	1 53	2 20	3 05	4 25	7 36	
	For Latitude 35°.								
0h.	15″	21″	27″	33″	40″	48″	57″	1′08″	1′21″
2	20	25	32	38	46	55	1 05	1 18	1 35
3	26	33	39	47	56	1′07	1 21	1 38	2 00
4	39	47	56	1′07	1′20	1 36	1 59	2 32	3 25
5	1′07	1′20	1′38	2 00	2 34	3 29	5 14	10 16	
	For Latitude 37° 30′.								
0h.	18″	24″	30″	36″	44″	52″	1′02″	1′14″	1′29″
2	22	28	35	42	50	1′00	1 12	1 26	1 45
3	29	36	43	52	1′02	1 14	1 29	1 49	2 16
4	43	51	1′01	1′13	1 27	1 49	2 14	2 54	4 05
5	1′11	1′26	1 54	2 10	2 49	3 55	6 15	14 58	

This allowance is of constant use where the surveyor fails to get an observation on the sun at noon, and is a very close approximation to the truth.

In running due east and west, as in tracing the standard parallels of latitude, the sights are set at 90° on the limb, and the line is run at right angles to the meridian.

If no allowance were made for the earth's curvature, these lines would, if sufficiently produced, reach the equator, to which they are constantly tending.

Of course, in running short lines either east or west, the variation from the parallel would be so small as to be of no practical importance; but when long sights are taken, the correction should be made by taking fore and back sights at every station, noticing the error on the back sight, and setting off one-half of it on the fore sight on the side towards the pole.

Time of Day by the Sun.—The time of day is best ascertained by the Solar Compass when the sun is on the meridian, as at the time of making the observation for latitude.

The time thus given is that of apparent noon, and can be reduced to mean time by merely applying the equation of time as directed in the Almanac, and adding or subtracting as the sun is slow or fast.

The time, of course, can also be taken before or after noon, by bringing the sun's image between the hour lines, and noticing the position of the divided edge of the revolving arm, with reference to the graduations of the hour circle, allowing four minutes of time for each degree of the arc, and thus obtaining apparent time, which must be corrected by the equation of time as just decribed.

Caution as to the False Image.—In using the compass upon the sun, if the revolving arm be turned a little one side of its proper position, a false or reflected image of the sun will appear on the silver plate in nearly the same place as that occupied by the true one. It is caused by the reflection of the true image from the surface of the arm, and is a fruitful source of error to the inexperienced surveyor. It can, however, be readily distinguished from the real image by being much less bright, and not so clearly defined.

Approximate Bearings.—When the bearings of lines, such as the course of a stream, or the boundaries of a forest, are not desired with the certainty given by the verniers and horizontal limb, a rough approximation of the angle they make with the true meridian is obtained by the divisions on the outside of the circular plate.

In this operation, a pencil, or thin straight edge of any sort, is held perpendicularly against the circular edge of the plate, and moved around until it is in range with the eye, the brass centre-pin, and the object observed.

The bearing of the line is then read off at the point where the pencil is placed.

Time for Using the Solar Compass.—The Solar Compass, like the ordinary instrument, can be used at all seasons of the year, the most favorable time being, of course, in the summer, when the declination is north, and the days are long, and more generally fair.

It is best not to take the sun at morning and evening, when it is within half an hour of the horizon, nor at noon, for about the same interval, before and after it passes the meridian.

Allowance for Refraction.—The proper allowance to be made for refraction in setting off the declination of the sun upon the Solar Compass has long been a source of perplexity to the surveyor; we have, accordingly, given the subject a good deal of attention, and here publish a table, by which the amount of refraction for any hour of any day of the year can be ascertained, and set off with a degree of accuracy which is all that can be desired.

A TABLE OF MEAN REFRACTIONS IN DECLINATION.

To apply on the declination arc of Solar Attachment of either Compasses or Transits.

Computed by EDWARD W. ARMS, C. E., for W. & L. E. GURLEY, Troy, N. Y.

HOUR ANGLE	DECLINATIONS.								
	For Latitude 30°.								
	+ 20°	+ 15°	+ 10°	+ 5°	0°	— 5°	—10°	—15°	—20°
0h.	10″	15″	21″	27″	33″	40″	48″	57″	1′08″
2	14	19	25	31	38	46	54	1′05	1 18
3	20	26	32	39	47	55	1′06	1 19	1 36
4	32	39	46	52	1′06	1′19	1 35	1 57	2 29
5	1′00	1′10	1′24	1′52	2 07	2 44	3 46	5 43	13 06
	For Latitude 32° 30′.								
0h.	13″	18″	24″	30″	36″	44″	52″	1′02″	1′14″
2	17	22	28	35	42	50	1′00	1 11	1 26
3	23	29	35	43	51	1′01	1 13	1 28	1 47
4	35	43	51	1′01	1′13	1 27	1 46	2 13	2 54
5	1′03	1′15	1′31	1 53	2 20	3 05	4 25	7 36	
	For Latitude 35°.								
0h.	15″	21″	27″	33″	40″	48″	57″	1′08″	1′21″
2	20	25	32	38	46	55	1 05	1 18	1 35
3	26	33	39	47	56	1′07	1 21	1 38	2 00
4	39	47	56	1′07	1′20	1 36	1 59	2 32	3 25
5	1′07	1′20	1′38	2 00	2 34	3 29	5 14	10 16	
	For Latitude 37° 30′.								
0h.	18″	24″	30″	36″	44″	52″	1′02″	1′14″	1′29″
2	22	28	35	42	50	1′00	1 12	1 26	1 45
3	29	36	43	52	1′02	1 14	1 29	1 49	2 16
4	43	51	1′01	1′13	1 27	1 49	2 14	2 54	4 05
5	1′11	1′26	1 54	2 10	2 49	3 55	6 15	14 58	

HOUR ANGLE.	DECLINATIONS.								
	For Latitude 40°.								
	+ 20°	+ 15°	+ 10°	+ 5°	0°	—5°	—10°	—15°	—20°
0h.	21″	27″	33″	40″	48″	57″	1′08″	1′21″	1′33″
2	25	32	39	46	52	1′06	1 19	1 35	1 57
3	33	40	48	57	1′08	1 21	1 38	2 02	2 36
4	47	55	1′06	1′19	1 36	1 58	2 30	3 21	4 59
5	1′15	1′31	1 51	2 20	3 05	4 25	7 34	25 18	
	For Latitude 42° 30′.								
0h.	24″	30″	36″	44″	52″	1′02″	1′14″	1′29″	1′49″
2	28	35	39	50	1′00	1 12	1 26	1 45	2 11
3	36	43	52	1′02	1 13	1 29	1 49	2 17	2 59
4	50	1′00	1′11	1 26	1 44	2 10	2 49	3 55	6 16
5	1′16	1 36	1 58	2 30	3 22	5 00	9 24		
	For Latitude 45°.								
0h.	27″	33″	40″	48″	57″	1′08″	1′21″	1′39″	2′02″
2	32	39	46	52	1′06	1 19	1 35	1 57	2 29
3	40	47	56	1′07	1 21	1 38	2 00	2 34	3 29
4	54	1′04	1′16	1 33	1 54	2 24	3 11	4 38	8 15
5	1′23	1 41	2 05	2 41	3 40	5 40	12 02		
	For Latitude 47° 30′.								
0h.	30″	36″	44″	52″	1′02″	1′14″	1′29″	1′49″	2′18″
2	35	42	50	1′00	1 12	1 26	1 45	2 01	2 51
3	43	51	1′01	1 13	1 28	1 47	2 15	2 56	4 08
4	56	1′09	1 23	1 40	2 05	2 40	3 39	5 37	11 18
5	1′27	1 46	2 12	2 52	4 01	6 30	16 19		
	For Latitude 50°.								
0h.	33″	40″	48″	57″	1′08″	1′21″	1′39″	2′02″	2′36″
2	38	46	55	1′06	1 18	1 35	1 57	2 28	3 19
3	47	56	1′06	1 19	1 36	2 29	2 31	3 23	5 02
4	1′02	1′44	1 29	1 48	2 16	2 58	4 18	6 59	19 47
5	1 30	1 51	2 19	3 04	4 22	7 28	24 10		
	For Latitude 52° 30′.								
0h.	36″	44″	52″	1′02″	1′14″	1′29″	1′49″	2′18″	3′05″
2	43	50	59	1 11	1 26	1 42	2 23	2 49	3 55
3	50	1′00	1′11	1 26	1 45	2 11	2 51	2 58	6 22
4	1′05	1 18	1 35	2 10	2 28	3 19	4 53	8 42	
5	1 34	1 56	2 27	3 16	4 47	8 52			

It has also a clamp-screw inserted near its centre, by which it can be set fast to the telescope axis in any desired position.

The vernier of the vertical limb is made movable by the tangent-screw attached, so that its zero and that of the limb are readily made to coincide when, in adjusting the limb to the level of the telescope, the arc is clamped to the axis.

The usual tangent movement to the telescope axis serves, of course, to bring the vertical limb to the proper elevation, as hereafter described.

A level on the under side of the telescope, with ground vial and scale, is indispensable in the use of the Solar attachment.

To Find the Latitude.—First level the instrument very carefully using the level of the telescope until the bubble will remain in the centre during a complete revolution of the instrument, the tangent movement of the telescope being used in connection with the leveling screws of the parallel plates, and the axis of the telescope firmly clamped.

Next clamp the vertical arc so that its zero and that of its vernier coincide as near as may be, and then bring them into exact line by the tangent-screw of the vernier.

Then, having the declination of the sun for 12 o'clock of the given day as affected by the meridional refraction carefully set off upon the declination arc, note also the equation of time and fifteen or twenty minutes before noon, the telescope being directed to the north, and the object end lowered until, by moving the instrument upon its spindle and the declination arc from side to side, the sun's image is brought nearly into position between the equatorial lines. Now bring the declination arc directly in line with the telescope, clamp the axis firmly, and with the tangent screw bring the image precisely between the lines and keep it there with the tangent screw, raising it as long as it runs below the lower equatorial line, or, in other words, as long as the sun continues to rise in the heavens.

When the sun reaches the meridian the image will remain stationary for an instant and then begin to rise on the plate.

The moment the image ceases to run below is of course apparent noon, when the index of the hour arc should indicate XII., and the latitude be determined by the reading of the vertical arc.

It must be remembered, however, that the angle through which the polar axis has moved in the operation just described is measured from the zenith instead of the horizon as in the ordinary solar, so that the angle read on the vertical limb is the complement of the latitude.

The latitude itself is readily found by subtracting this angle from 90°; thus at Troy, the reading of the limb being found as above directed to be 47° 16′, the latitude will be $90° - 47° \; 16' = 42° \; 44'$.

It will be noticed that with this apparatus the latitude of any place can be most easily ascertained without any index error, as in the usual solar compass.

To run lines with the Solar Attachment.—Having set off the complement of the latitude of the place on the vertical arc, and the declination for the given day and hour as in the solar, the instrument being also *carefully* leveled by the telescope bubble, set the horizontal limb at zero and clamp the plates together, loosen the lower clamp so that the transit moves easily upon its lower socket, set the instrument approximately north and south, the object end of the telescope pointing to the north, turn the proper solar lens to the sun, and with one hand on the plates and the other on the revolving arm, move them from side to side until the sun's image is brought between the equatorial lines on the silver plate.

The lower clamp of the instrument should now be fastened, and any further lateral movement be made by the tangent screw of the tripod. The necessary allowance being made for refraction, the telescope will be in the true meridian, and being unclamped, may be used like the sights of the ordinary solar compass, but with far greater accuracy and satisfaction in establishing meridian lines. Of course when the upper or vernier plate is unclamped from the limb, any angle read by the verniers is an angle from the meridian, and thus parallels of latitude or any other angles from the true meridian may be established as with the solar compass.

The bearing of the needle, when the telescope is on the meridian, will also give the variation of the needle at the point of observation.

If the instrument has a movable compass circle, the variation of the needle can be set off to single minutes, the needle kept at zero, or "with the sun," and thus lines be run by the needle alone when the sun is obscured.

APPENDIX B.

THE SEXTANT.*

(By Prof. J. K. Rees, Columbia College.)

This instrument is especially useful to the scientific explorer on account of its portability and simplicity of manipulation. It requires no fixed support, and furnishes data with the least expenditure of the time of the observer. The accuracy of fixed instruments is not to be expected from it, since it is held in the hand and is of small dimensions.

The Principle of the Instrument.—The optical principle upon which the sextant is made is :—If a ray of light suffers two successive reflections in the same plane by two plane mirrors, the angle between the first and last directions of the ray is twice the angle of the mirrors.

Let *I* and *H* be two plane mirrors perpendicular to the plane of the paper,—which is taken as the plane of reflection.

A ray of light from *A* is reflected, first from the mirror *I* in the direction *CO*, then by the mirror *H* along *OT*. The angle between the first and last direction of the ray after these two reflections is *ATO*.

Draw *CN* and *OM* normal to the mirrors *I* and *H* respectively. Then *NKO* equals the angle of the mirrors.

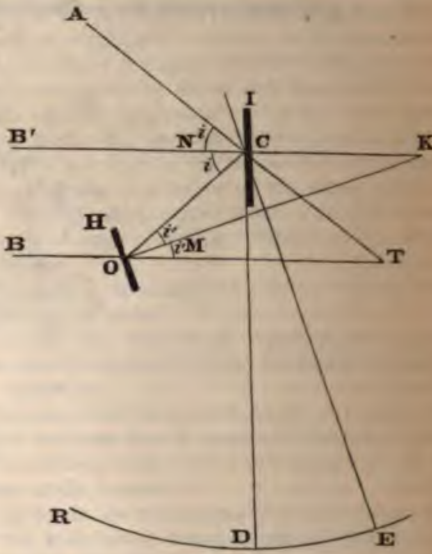


Fig. 4.

From the law of the reflection of light it is known that the angle

$$ACN \text{ or } i = \text{angle } NCO\,;$$

and also,

$$COM \text{ or } i' = MOT.$$

---

* For a full description of this instrument, see Chauvenet's Spherical and Practical Astronomy, published by Lippincott in 1863.

ce angle $ATO = 2i - 2i'$;

angle $NKO = i - i'$;

$\therefore$ $ATO = 2NKO$. Q. E. D.

Suppose now that the glass H is unsilvered on the upper half; then a ray of light coming from B will pass through this unsilvered portion to T, and the angle ATO will measure the angular distance of A from B as seen at T.

To apply this principle the mirror I, revolving about a pivot at C, has attached to it an arm or bar ID, which, as the mirror is turned, moves over a graduated arc ER. The mirror H is fixed in position. There will be one position of the index arm where the two mirrors will be parallel. Then since the angle between the first and last directions of the ray of light which is reflected by both mirrors is zero, or the two directions are parallel, the indicated point of the graduated arc is marked zero. The graduations are then continued to the left, calling each degree two degrees, in order to read off at once the required angle.

The best form of the common sextant is seen in the accompanying cut, furnished by Messrs. Stackpole & Brother, N. Y.:

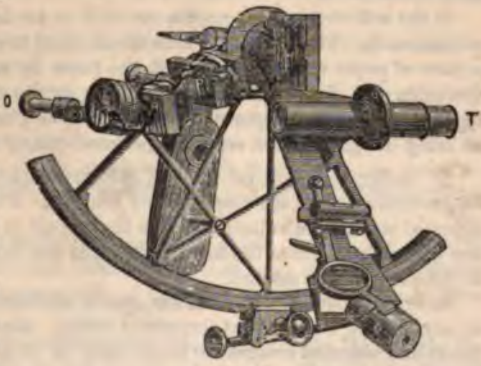


FIG. 5.

The frame is of brass, constructed so as to combine strength with lightness; the graduated arc, inlaid in the brass, is usually of silver. The divisions of the arc are ordinarily 10′ each, which are subdivided by the vernier to 10″. The handle A by which it is held in the hand is of wood.

The mirrors I and H are of plate glass silvered. The upper half of the glass H is left unsilvered in order that the direct rays from a distant object may not be interrupted. To give greater distinctness to the images a small telescope T is placed in the line of sight OT. The telescope is supported in a ring D, which can be moved in a direction at right angles to the plane of the sextant. Thus the axis of the telescope can be directed either towards the silvered or the unsilvered part of the mirror. This motion changes the plane of reflection, which, however, remains always parallel to the plane of the sextant; the use of the motion being merely to regulate the relative brightness of the direct and reflected images. The vernier is read with the aid of a glass G which is attached to the index bar. The central mirror I, or *index glass*, is fastened in a brass frame which is firmly attached to the index bar by three screws. This glass is generally set by the maker so as to be perpendicular to the plane of the sextant. There are no adjusting screws usually connected with it. The fixed mirror H, or *horizon glass* (so called because through it the horizon is observed in takin altitudes), is specially provided with screws by which its position with respect to the sextant plane may be rectified.

At P and Q are colored glasses of different shades, which may be used separately or in combination, to defend the eye from the intense light of the sun.

Common Adjustments of Ordinary Sextant.

1. The Index Glass must be perpendicular to the plane of the sextant.

2. The Horizon Glass must also be perpendicular to the plane of the sextant.

3. The central sight line of the telescope must be parallel to the plane of the sextant.

4. The true zero of the arc must be found.

1. Adjustment of the Index Glass.—Bring the vernier to about the middle of the graduated arc; then, placing the eye a little above the plane of the sextant and near the index glass, examine the direct and reflected images of the graduated arc. If the one appears to run into the other the index glass is perpendicular to the plane of the sextant, and the adjustment is complete.

If the reflected image appears too high or too low the glass leans forward or backward. The glass may then be adjusted to perpendicularity by placing a piece of paper under one edge of the plate by which the glass is held to the index arm, first loosening the screws; or the glass may be taken out of the frame, and the supports against which the glass leans may be filed so as to bring the glass, when set back, perpendicularly to the plane of the sextant.

2. Adjustment of the Horizon Glass.—This glass must also be perpendicular to the plane of the sextant. The index glass having been adjusted to perpendicularity, if it is found that in any one position the horizon glass is parallel to the index glass, then the horizon glass is perpendicular to the plane of the sextant.

In order to test this parallelism, put in the telescope and direct it to a star or any distant, well-defined terrestrial object. Move the index bar until the direct and reflected images are in the field of view, then clamp the vernier, and by moving the tangent screw cause one image to pass the other; if they pass exactly one over the other the adjustment is complete; if they pass one at the side of the other, the horizon glass must be adjusted. There are adjusting screws attached to the glass whereby it can be inclined to or from the sextant plane, and also turned around an axis perpendicular to the sextant plane. By means of the first set of screws the adjustment for perpendicularity can be made, and by means of the second set the position of the zero of the limb can be altered to a small extent.

3. Adjustment of the Telescope.—The sight line of the telescope is the line from the centre of the field of view through the centre of the object glass. This line must be parallel to the plane of the sextant. In order to test for this, choose two distant objects like the sun and moon, 90° to 120° apart; direct the telescope to one of these objects, holding the plane of the sextant so as to pass through both; then moving the index bar, bring the second object into the field of view; clamp the vernier, turn the tangent screw until the two objects are tangent to each other on the thread of the telescope nearest to the instrument. Then by moving the instrument, cause the objects to come on the thread farthest from the instrument. If the tangency is still perfect, the adjustment is complete. If the objects separate upon the thread farthest from the instrument, then the object end of the telescope droops towards the plane of the instrument: if the images overlap, then the telescope inclines upward from the plane of the instrument. The adjustment is made by means of the screws that work into the collar which carries the telescope.

4. Index Correction.—When the two glasses are parallel the zero of the graduated limb should coincide with the zero of the vernier. This adjustment must be very carefully looked after before taking any observations, because it is an adjustment that is liable to change. Rather than make this adjustment accurately every time an observation is made it is preferable to determine the place of the true zero of the graduated arc and allow for the correction. This correction is simply the distance between the graduated zero of the instrument and the reading of the vernier when the two mirrors are parallel. This correction is minus when it is on the graduated arc towards the increasing numbers of the graduation, and plus when on the opposite side.

The index correction may be determined by observations upon a star, or a distant, well-defined, terrestrial object, or upon the sun.

First, by a star: Direct the telescope to a star of the third or fourth magnitude; move the index bar until the reflected image of this star comes into the field of view; then clamp the vernier; turn the tangent screw until the direct and reflected images of the star are exactly in coincidence; take the reading of the vernier; apply the proper sign, and the arc reading is the index correction.

Second, by a distant, well-defined terrestrial object, or the reflection of sunlight from—for example—the bulb of a thermometer or a drop of water. This can be observed in the same way as a star, although not giving as accurate results.

Third, by the sun: Turn on the colored glasses until the light from the sun is diminished sufficiently to suit the eye; bring the direct and reflected images of the sun into the field of view; clamp the vernier; turn the tangent screw until one image of the sun is tangent to the other; take the reading; turn the tangent screw until the contact is broken; bring the images back to tangency; take the reading again; in this way make five readings; then turn the tangent screw until the images change places and tangency is made on the other side; take the same number of readings here.

In order to read always from the same end of the vernier, call the zero of the vernier 360°, and read the vernier accordingly. Take the mean of the readings in the first and second cases, add them together, and divide by two. Subtract the result from 360°, and the difference will be the index correction.

In order to avoid the effect of refraction it is best to measure the horizontal diameter of the sun. To check the observations compute the diameter of the sun from data given in the Nautical Almanac, for the day of the observation, and compare it with the diameter of the sun as obtained from the observations.

NOTE.—Let R be the true reading of the vernier when the mirrors are parallel; let S be the diameter of the sun; let r be the reading of the vernier when contact is made on the left of the zero of the instrument, and r' the reading when the contact is made on the right.

Then,
$$r = R + S$$
$$r' = R - S.$$

Hence,
$$R = \frac{r + r'}{2},$$

and
$$S = \frac{r - r'}{2}$$

June 1st, 1883.—10 A. M.

Observed sun for index correction.

ON ARC.		OFF ARC.
360° 34′ 10″		359 30 50
10″		45
5		45
10		55
0		50
360 34 07 = r	means	359 30 49 = r'
359 30 49		360 34 07
2)720 4 56		2) 1 3 18
360 2 28		Observed diam. sun, 31 39.
Index correction,		Calculated diam. sun, 31 36.7
−2′ 28″		Difference, ... 2.3

To Measure the Angular Distance between two objects with the Sextant.

Turn the eye-piece until two of the reticule threads of the telescope are parallel to the plane of the instrument; then direct the telescope to the fainter of the two objects; move the plane of the instrument until it passes through the two objects; revolve the index bar until the reflected image of the second object appears in the field of view; clamp the vernier; with the tangent screw make the two images coincide. The reading of the vernier with the index correction applied will be the angular distance of the two objects. The index glass must always be on the side towards the second object. The coincidence must be made at the middle point of the field of view. Care must be taken to have the relative brightness of the two objects about the same.

Altitudes of objects may be obtained in a similar way, holding the plane of the sextant vertical.

APPENDIX C.

INSTRUCTIONS TO DEPUTY U. S. MINERAL SURYEYORS.

SURVEYOR GENERAL'S OFFICE,
DENVER, COLORADO, *June* 1, 1880.

SIR :—The following instructions have been prepared for your government in making mineral surveys :

1. You can make no official survey without an order from this office.

2. To procure an order for survey, the application should be made in writing, accompanied with a copy of the certificate of location of the claim to be surveyed, duly certified by the proper recorder, and inclosing a deposit of $25 for office work. Be careful to state plainly the name of the person or persons who desire the survey.

3. An order will not be issued unless in the judgment of this office the certificate of location is in accordance with law and regulations.

4. For the accommodation of claimants residing remote from a United States Depository, this office will see that the deposit is made when the proper funds are received. Send Post Office order, draft or check, on Denver, as other drafts cannot be used without discount.

5. Should the original certificate of location be found defective, and the description does not cover the ground claimed, an *additional* or *amended* certificate may be filed as provided by section 13 of the laws of Colorado, approved February 13th, 1874, and a certified copy of the amended certificate must be sent to this office, and your survey dated subsequent to the filing of the same in the proper recorder's office.

6. Certificates of location are frequently sent, which any well-informed deputy should KNOW are too indefinite ; examine them carefully before sending, and it will save yourselves and this office much trouble, and remember that your survey MUST AGREE with certificate of location.

7. "If the records of locations made *prior* to the passage of the mining act of May 10th, 1872, are not sufficiently definite and certain to enable you to make a correct survey therefrom, you should, after reasonable notice in writing, to be served personally, or through the United States mail, on the applicant for survey and adjoining claimants (whose residence or Post Office address you may know or can ascertain by the exercise of reasonable diligence), take the testimony of neighboring claimants and other persons who are familiar with the boundaries thereof as originally located and asserted by the locators of the claim, and after having ascertained by such testimony the

boundaries as originally established, you should make a survey in accordance therewith, and transmit full and correct returns of survey, accompanied by the copy of the record of location, the testimony, and a copy of the notice served on the claimant and adjoining proprietors, certifying thereon when, in what manner, and on whom, service was made."

8. The act of Congress of May 10th, 1872, expressly provides that "the location must be distinctly marked on the ground, so that its boundaries can be readily traced," and "that all records of mining claims hereafter made shall contain the name or names of the locators, the date of location, and such a description of the claim or claims, located by reference to some natural object or permanent monument, as will identify the claim."

9. "These provisions of the law must be strictly complied with in each case to entitle a claimant to a survey and patent, and therefore should a claimant under a location made *subsequent* to the passage of the mining act of May 10th, 1872, who has not complied with said requirements in regard to marking the location upon the ground, and recording the same, apply for a survey," I "will decline to order it."

10. "The only relief for a party under such circumstances will be to make a new location in conformity to law and regulations, as no case will be approved by this office unless these and all other provisions of law are substantially complied with."

11 Corners must be established in as permanent a manner as possible, and should consist of rock in place, or tree if they are found at the exact point; otherwise a STONE, not less than two feet long, set one foot in the ground; or POSTS, not less than *four inches in diameter*, planted two feet in the ground and protruding not less than two and not more than four feet above ground; both stones and posts must be protected with a mound of stone or earth in addition to the planting.

12. Each corner to be marked No. 1, 2, etc., also the number of the survey, as you proceed with the work, giving in field notes, bearings and distances from each corner to rocks or trees, if any such are at convenient distance, marking same with number of corner and number of survey, and describe marks. Wooden posts and trees must be marked with a scribe, and rocks with a chisel. Give, from at least two corners of the survey, two or more bearings to well known points, such as mountain peaks, confluence of streams, etc., both in field notes and on plats. If any portion of this section cannot be complied with, so state it in field notes.

13. Note all objects crossed by your line of survey, such as previous surveys, lodes, ditches, roads, ravines, etc., etc., and show them upon plat. "If in running the exterior boundaries of a claim it is found that two surveys conflict, the plats and field notes should show the extent of the conflict, giving the area embraced in both surveys, and also the courses and distances from the established corners at which the exterior boundaries of the respective surveys intersect each other. In notes give area as follows:

Total area,	5.94 acres.
Less area in conflict with surveys Nos. 13 and 17,	2.00 acres.
Leaving net area,	3.94 acres.

On plat give net area only.

14. Connect corner No. 1 of your survey with some corner of the public survey if the claim is located within two miles of such public survey. From corner No. 1 beginning you will proceed with the survey of the claim, giving distances in feet and true courses, as you proceed establishing a corner at each angle of the survey. If an official survey has been made in the same vicinity, run a connecting line to some corner of the same. Surveys must be made to close exactly. Mention particularly all adjoining claimants.

15. In referring to other surveys give in your field notes the name and number of each survey, and name of claimant or owner. When referring to a survey more than once it is unnecessary to repeat more than the number.

16. See Section 2320, Revised Statutes of the United States, in regard to width of lode claims "on each side of the middle of the vein at the surface." When the locator does not determine, by exploration, *where* the middle of the vein at the surface is, his discovery shaft must be assumed to mark such point."

17. You will give the quarter section, township and range in which the claim is situated, in notes and on plat, showing section lines on your plat in black, and quarter section lines in red.

18. In districts where there are no public surveys within two miles of your survey, and no locating monument previously established within one hundred chains of such survey, you will establish a LOCATING MONUMENT at some well-known point, a rock in place being preferable; but if such cannot be found, then erect a large substantial mound of rocks, describing the same fully in your notes, and hereafter chisel upon it a name, using this as a starting point for your surveys, and when the public surveys reach the locality, run a connecting line from the monument to a corner in said surveys, thus connecting all claims surveyed from the monument.

19. Note all improvements upon the claim, such as shafts, drifts, adits, cuts, buildings, etc., giving the extent of same. Show improvements on plat and locate them in field notes, by course and distance, in a direct line from some corner of the survey.

20. After describing fully the improvements (stating if the excavations are in dirt or rock) placed on the claim by the claimant or his grantors, say that "the value of the said improvements, together with the labor expended on the said claim by the claimant (or his grantors, as the case may be) is not less than five hundred dollars." If $500 in improvements has not been expended at time of survey the work may be performed and certificate of Surveyor-General filed at the land office during the 60 days of advertising. To obtain this certificate the deputy must send his affidavit stating that the sum of $500 has been expended, describing improvements fully. In estimating the value of improvements only actual mining improvements should be considered.

21. "From an examination of the returns of surveys of mining claims, I am satisfied that in many instances the deputy surveyors certify to the value of improvements without ascertaining whether such improvements are made by the claimant or his grantors, or other persons."

22. "No improvements should be included in the estimate unless they have been made by the applicant for survey, or by those from whom he derives his title, and so stated in your notes."

23. "The value of improvements made upon other locations, or by other

persons, should not be taken into consideration, but excluded by deputies in their estimate of improvements upon the claim."

24. Following description of improvements made by the claimant, locate the improvements made by other persons, in the manner described in Sec. 19.

25. State all facts coming to your knowledge in regard to adjoining conflicting claimants, whether their claims are surveyed or not.

26. Your field notes should be complete in themselves, leaving nothing to be explained by letter; and as they are bound in book form after approval you should leave margin for binding. Fold notes so as to leave as little blank paper as possible, and stitch them together.

27. If you know your survey does not agree with that of other deputies you should communicate with such deputy before sending your survey to this office, and try to reconcile all discrepancies; if it cannot be adjusted, report to this office, and a joint survey will be ordered upon knowing that this section has been complied with.

28. When a joint survey is ordered, the deputy who discovers the supposed error will be directed to call upon the deputy supposed to be in error, and see if the discrepancy cannot be reconciled. If they cannot agree, then they shall make a joint survey within ten days after the date of the order. When said survey is completed they shall make a joint affidavit to the field notes, and forward them to this office. The deputy found to be in error shall pay all expenses, including $10 per day to the deputy whose work is found to be correct. If both deputies are found to be in such error as to require amended field notes of their former survey, then each deputy shall pay one-half the expenses of the joint survey. Any deputy refusing or neglecting to appear for the joint survey, within the ten days named, or who shall refuse or neglect to pay the expenses as above indicated, will be suspended; and if the refusal or neglect shall extend to twenty days, his commission as deputy will be revoked.

29. In preparing plats make the top North, and color only the ground not in conflict. Mark upon the plat all corners (thus, "Cor. No 1," etc.), courses to mountain peaks, courses and distances to all connecting lines and upon the boundaries of the survey. Plat survey upon as large a scale as paper will admit of, if practicable not less than 200 feet to the inch. Be careful that your plats and notes agree.

30. An applicant has the right to abandon, from his application for patent, any part or portion of the premises embraced in the survey, but in case he does abandon any portion of the premises embraced by his application and survey, it will be necessary that an amended survey be made *upon application of the claimant*, and as such amended survey involves as much office work as the original survey, the usual deposit should accompany the claimant's application for the amended survey.

31. After this date surveys will be approved in the order in which they are received, deputies being required to act promptly in all official matters, that the approval of a survey may not be unnecessarily delayed. In case of unreasonable delay on the part of the deputy to correct errors, the survey will be stricken from the files, and the applicant notified.

32. In order that all returns may be made uniform, blank plats and field note paper will be furnished from this office for your use, which blanks you will fill [illegible] se may require. You will be careful that the names of

claimants and number of survey agree with the order for survey and certificate of location. You will make one copy of the plat and notes and transmit the same to this office, prepaying the postage or express, in full; otherwise they will not be received. Do not fold plats for transmission, but *roll* them. As your plat and notes come under the head of "written matter," they require letter postage.

33. Unless plats and notes are prepared in a neat and workmanlike manner they will not be accepted. Plats and notes are often found to be incorrect from negligence, carelessness and ignorance. Many deputies appear to depend upon this office to detect and correct these errors, as it saves them the trouble. Hereafter such surveys will be returned with the simple statement that "they are incorrect."

34. A *solar transit* MUST be used in all official surveys being guided by the solar apparatus, and not the needle, unless the courses are deflected from a meridian astronomically established. On account of local attractions a needle instrument will not be accepted as reliable. State in field notes the kind of instrument used, and the manner in which the courses are taken.

35. "You are informed that the employment of Deputy Mineral Surveyors as attorneys in mineral claims, directly or indirectly, is absolutely prohibited," and you will make no survey in which you are interested.

36. Be particular to write all proper names *plainly*.

37. Deputies changing their residence should notify this office of such change.

38. I shall expect you to make yourself thoroughly familiar with all the mining laws, National and State, as well as with these instructions, and I am sure that errors will be less frequent, and this office as well as yourself will be relieved of much annoyance.

39. All official communications must be addressed to the Surveyor General, and not to clerks in his office.

Very respectfully,
ALBERT JOHNSON,
Surveyor General of Colorado.

Sample Field Notes furnished Deputies.

SURVEY NO. 500, DISTRICT NO. 3.

FIELD NOTES

Of the survey of the claim of...
.........................John H. Marshall,.....................................
upon the.......................Excelsior...........................Lode,
in....................California..........................Mining District,
...................Lake ....County, Colorado.

Surveyed by..........George D. Williams,.................................
U. S. Deputy Mineral Surveyor.
Survey begun ....October 23d,...................1881,
and completed.........................." 28th,..................1881.

Feet.	
	DESCRIPTION OF SURVEY. Beginning at Cor. No. 1, a spruce post, 5 ft. long, 4 ins. diam., set 2 ft. in the ground, with mound of stone, marked $\frac{1}{500}$ whence the W. ¼, cor. in sec. 16, T. 8 S., R. 80 W. of the 6th Prin. Mer. bears, S. 84° 26′ W. 1847. 4 ft. A spruce, 6 ins. diam , marked B. T. $\frac{1}{500}$, bears S. 78° 32′ W. 32.9 ft. Thence N. 11° 53′ E. Var. 14° 15′ E.
300.	To Cor. No. 2. A spruce post 4 ft. long, 4 ins. dia., set 2 ft. in ground, with mound of earth marked $\frac{2}{500}$, whence, Holy Cross Mt. bears N. 41° 37′ W.; Mt. Leon bears N. 14° 29′ W. (No other bearings available.) Thence S. 78° 7′ E. Var. 14° 15′ E.
92.	To road running S. Easterly.
224.27	Intersect line 4-1 of Sur. No. 495, Treasury lode, John P. Jones et al. claimants, N. 15° E. 79.91 ft. from Cor. No. 4.
952.72	Intersect line 4-1 of Sur. No. 227, Silver Dollar Lode, Henry J. Smith, claimant, at S. 3° W. 401.02 ft. from Cor. No. 1.
1256.36	Intersect line 2-3 of Sur. No. 227, S. 3° W. 447. 9 ft. from Cor. No. 2.
1500.	To Cor. No. 3.

Feet.	
	A granite stone 25 × 11 × 7 ins., se in ground, with mound of stones, chiseled $\frac{3}{500}$, whence a spruce 6 ins. dia., marked B. T. $\frac{3}{500}$, bears S. 80° 23′ E. 20.4 ft.; B. R. $\frac{3}{500}$ chiseled on rock in place, bears N. 44° E. 30 ft.
	Thence S. 11° 53′ W. Var. 14° 55′ E.
149.5	Intersect line 3-4 of Sur. No. 495, at N. 75° W., 218 ft. from Cor. No. 3.
198.	To Gulch; course N. E.
300.	To Cor. No. 4.
	A quartz stone 24 × 13 × 8 ins., set 1 ft. in ground, and mound of stone, chiseled $\frac{4}{500}$, whence B. R. $\frac{4}{500}$ chiseled on large boulder, bears N. 38° 22′ W. 25.4 ft.
	Mt. Leon bears N. 19° 22′ W. Sherman Peak bears S. 84° 45′ E. Cor. No. 3, Sur. No. 495, bears N. 69° 23′ E. 258 ft. Cor. No. 3, Sur. 227, bears S. 18° 9′ W. 743.9 ft.
	Thence N. 78° 7′ W. Var. 14° 55′ E.
112.	To Gulch.
196.75	Intersect line 2-3 of Sur. No. 227, N. 8° E., 748.45 ft. from Cor. No. 3.
500.39	Intersect line 4-1 of Sur. No. 227, N. 8° E., 795.84 ft. from Cor. No. 4.
911.	To road.
1500.	To Cor. No. 1, place of beginning.

AREA.

Containing	10.32 acres.
Less conflicts with	
Sur. No. 227=2.12 acres	
" " 495=2.46 "	4.58 "
Leaving net area	5.74 acres.

LOCATION.

This survey is located in the N. ½ and S. E. ¼ of Sec. 16, in T. 8 S., R. 80 W.

IMPROVEMENTS

Upon this claim consist of:

A discovery shaft, 5′ × 3′, 275 ft. deep, timbered, which bears from Cor. No. 1, N. 64° 59′ E. 250.6 ft.

A log shaft-house, 56′ × 40′, the S. W. corner of which bears from Cor. No. 1, N. 65′ 26′ E. 207 ft.

A shaft 4′ × 4′, 25 ft. deep, which bears from Cor. No. 1, N. 88° 39 E. 765 ft.

An open cut 3′ × 10′, which bears from Cor. No. 3, S. 58° 45′ W. 264 ft.

I hereby certify that the value of said improvements, together with the labor expended on the said claim by the claimant and his grantors, is not less than Five Hundred Dollars ($500).

Improvements made by other parties are as follows:

A shaft 4′ × 6′, 78 feet deep, which bears from Cor. No. 3, N. 83° 27′ W. 389 ft.

ADJOINING CLAIMS.

Surveys Nos. 495 and 227. No others known.

INSTRUMENTS USED.

A Gurley Mountain Transit, with solar attachment (or the instrument used), and steel tape (or the measure used).

All courses determined by the use of the solar apparatus.

ADDRESS OF APPLICANT,

JOHN H. MARSHALL,
P. O. Box 743, Leadville, Colo.

[Then follow a list of the assistants employed in making the survey, with their affidavit as to its conformity to instructions, the affidavit of the Deputy Mineral Surveyor, and the certificate of the Surveyor General.]

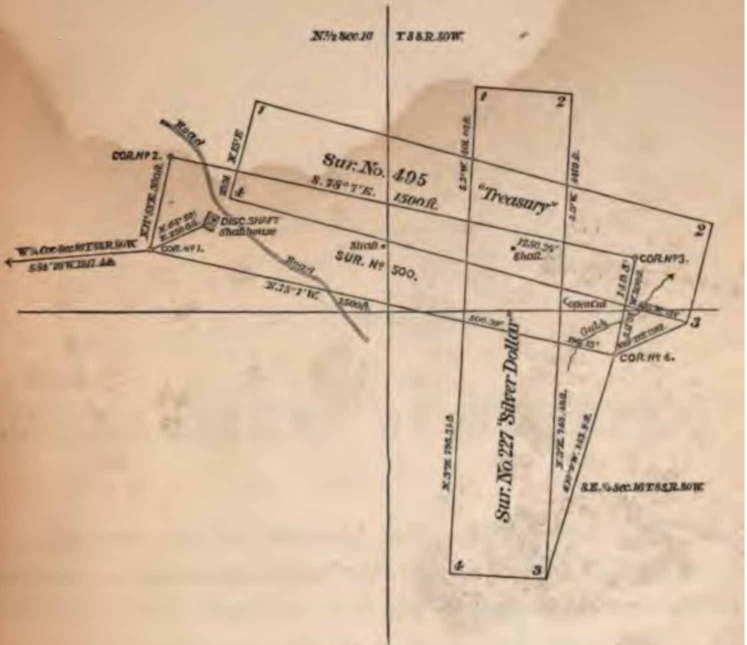


FIG. 6.

SURVEY No. 500.
MINERAL DISTRICT No 3.

PLAT of the claim of JOHN H. MARSHALL upon the EXCELSIOR LODE, California Mining District,..........Lake,.... .....County, STATE OF COLORADO. Containing an area of....5.74....acres. Scale of.... 200... feet to the inch. Variation....East. Surveyed by Geo. D. Williams, U. S. Deputy Mineral Surveyor.

October 28, 1881.

The Original Field Notes of the Survey of the Claim of...upon the..........................from which this plat has been made, have been examined and approved, and are on file in this office; and I hereby certify that they furnish such an accurate description of said Mining Claim as will, if incorporated into a patent, serve fully to identify the premises, and that such reference is made therein to natural objects and permanent monuments as will perpetuate and fix the locus thereof. I further certify that the value of the labor and improvements placed thereon by the applicant, or his grantors, is not less than Five Hundred Dollars, and that said improvements consist of:...as appears by the report of the Deputy Surveyor. And I further certify that this is a correct Plat of said Mining Claim, made in conformity with said field notes of the survey thereof.

U. S. Surveyor General's Office,
Denver, Colorado.
..........................18...
....
U. S. Surveyor General for Colorado.

A TABLE

OF

LOGARITHMS OF NUMBERS.

Remark.—In the following table, in the nine right hand columns of each page, where the first or leading figures change from 9's to 0's, points or dots are introduced instead of the 0's, to catch the eye, and to indicate that from thence the two figures of the Logarithm to be taken from the second column, stand in the next line below.

N.	0	1	2	3	4	5	6	7	8	9	D.
100	000000	0434	0868	1301	1734	2166	2598	3029	3461	3891	432
101	4321	4751	5181	5609	6038	6466	6894	7321	7748	8174	428
102	8600	9026	9451	9876	•300	•724	1147	1570	1993	2415	424
103	012837	3259	3680	4100	4521	4940	5360	5779	6197	6616	419
104	7033	7451	7868	8284	8700	9116	9532	9947	•361	•775	416
105	021189	1603	2016	2428	2841	3252	3664	4075	4486	4896	412
106	5306	5715	6125	6533	6942	7350	7757	8164	8571	8978	408
107	9384	9789	•195	•600	1004	1408	1812	2216	2619	3021	404
108	033424	3826	4227	4628	5029	5430	5830	6230	6629	7028	400
109	7426	7825	8223	8620	9017	9414	9811	•207	•602	•998	396
110	041393	1787	2182	2576	2969	3362	3755	4148	4540	4932	393
111	5323	5714	6105	6495	6885	7275	7664	8053	8442	8830	389
112	9218	9606	9993	•380	•766	1153	1538	1924	2309	2694	386
113	053078	3463	3846	4230	4613	4996	5378	5760	6142	6524	382
114	6905	7286	7666	8046	8426	8805	9185	9563	9942	•320	379
115	060698	1075	1452	1829	2206	2582	2958	3333	3709	4083	376
116	4458	4832	5206	5580	5953	6326	6699	7071	7443	7815	372
117	8186	8557	8928	9298	9668	••38	•407	•776	1145	1514	369
118	071882	2250	2617	2985	3352	3718	4085	4451	4816	5182	366
119	5547	5912	6276	6640	7004	7368	7731	8094	8457	8819	363
120	079181	9543	9904	•266	•626	•987	1347	1707	2067	2426	360
121	082785	3144	3503	3861	4219	4576	4934	5291	5647	6004	357
122	6360	6716	7071	7426	7781	8136	8490	8845	9198	9552	355
123	9905	•258	•611	•963	1315	1667	2018	2370	2721	3071	351
124	093422	3772	4122	4471	4820	5169	5518	5866	6215	6562	349
125	6910	7257	7604	7951	8298	8644	8990	9335	9681	••26	346
126	100371	0715	1059	1403	1747	2091	2434	2777	3119	3462	343
127	3804	4146	4487	4828	5169	5510	5851	6191	6531	6871	340
128	7210	7549	7888	8227	8565	8903	9241	9579	9916	•253	338
129	110590	0926	1263	1599	1934	2270	2605	2940	3275	3609	335
130	113943	4277	4611	4944	5278	5611	5943	6276	6608	6940	333
131	7271	7603	7934	8265	8595	8926	9256	9586	9915	•245	330
132	120574	0903	1231	1560	1888	2216	2544	2871	3198	3525	328
133	3852	4178	4504	4830	5156	5481	5806	6131	6456	6781	325
134	7105	7429	7753	8076	8399	8722	9045	9368	9690	••12	323
135	130334	0655	0977	1298	1619	1939	2260	2580	2900	3219	321
136	3539	3858	4177	4496	4814	5133	5451	5769	6086	6403	318
137	6721	7037	7354	7671	7987	8303	8618	8934	9249	9564	315
138	9879	•194	•508	•822	1136	1450	1763	2076	2389	2702	314
139	143015	3327	3639	3951	4263	4574	4885	5196	5507	5818	311
140	146128	6438	6748	7058	7367	7676	7985	8294	8603	8911	309
141	9219	9527	9835	•142	•449	•756	1063	1370	1676	1982	307
142	152288	2594	2900	3205	3510	3815	4120	4424	4728	5032	305
143	5336	5640	5943	6246	6549	6852	7154	7457	7759	8061	303
144	8362	8664	8965	9266	9567	9868	•168	•469	•769	1068	301
145	161368	1667	1967	2266	2564	2863	3161	3460	3758	4055	299
146	4353	4650	4947	5244	5541	5838	6134	6430	6726	7022	297
147	7317	7613	7908	8203	8497	8792	9086	9380	9674	9968	295
148	170262	0555	0848	1141	1434	1726	2019	2311	2603	2895	293
149	3186	3478	3769	4060	4351	4641	4932	5222	5512	5802	291
150	176091	6381	6670	6959	7248	7536	7825	8113	8401	8689	289
151	8977	9264	9552	9839	•126	•413	•699	•985	1272	1558	287
152	181844	2129	2415	2700	2985	3270	3555	3839	4123	4407	285
153	4691	4975	5259	5542	5825	6108	6391	6674	6956	7239	283
154	7521	7803	8084	8366	8647	8928	9209	9490	9771	••51	281
155	190332	0612	0892	1171	1451	1730	2010	2289	2567	2846	279
156	3125	3403	3681	3959	4237	4514	4792	5069	5346	5623	278
157	5899	6176	6453	6729	7005	7281	7556	7832	8107	8382	276
158	8657	8932	9206	9481	9755	••29	•303	•577	•850	1124	274
159	201397	1670	1943	2216	2488	2761	3033	3305	3577	3848	272
N.	0	1	2	3	4	5	6	7	8	9	D.

N.	0	1	2	3	4	5	6	7	8	9	D.
160	204120	4391	4663	4934	5204	5475	5746	6016	6286	6556	271
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384	4331	4444	4557	4670	4783	4896	5009	5122	5235	5348	113
385	5461	5574	5686	5799	5912	6024	6137	6250	6362	6475	113
386	6587	6700	6812	6925	7037	7149	7262	7374	7486	7599	112
387	7711	7823	7935	8047	8160	8272	8384	8496	8608	8720	112
388	8832	8944	9056	9167	9279	9391	9503	9615	9726	9838	112
389	9950	••61	•173	•284	•396	•507	•619	•730	•842	•953	111
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391	2177	2288	2399	2510	2621	2732	2843	2954	3064	3175	111
392	3286	3397	3508	3618	3729	3840	3950	4061	4171	4282	111
393	4393	4503	4614	4724	4834	4945	5055	5165	5276	5386	110
394	5496	5606	5717	5827	5937	6047	6157	6267	6377	6487	110
395	6597	6707	6817	6927	7037	7146	7256	7366	7476	7586	110
396	7695	7805	7914	8024	8134	8243	8353	8462	8572	8681	110
397	8791	8900	9009	9119	9228	9337	9446	9556	9665	9774	109
398	9883	9992	•101	•210	•319	•428	•537	•646	•755	•864	109
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402	4226	4334	4442	4550	4658	4766	4874	4982	5089	5197	108
403	5305	5413	5521	5628	5736	5844	5951	6059	6166	6274	108
404	6381	6489	6596	6704	6811	6919	7026	7133	7241	7348	107
405	7455	7562	7669	7777	7884	7991	8098	8205	8312	8419	107
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410	612784	2890	2996	3102	3207	3313	3419	3525	3630	3736	106
411	3842	3947	4053	4159	4264	4370	4475	4581	4686	4792	106
412	4897	5003	5108	5213	5319	5424	5529	5634	5740	5845	105
413	5950	6055	6160	6265	6370	6476	6581	6686	6790	6895	105
414	7000	7105	7210	7315	7420	7525	7629	7734	7839	7943	105
415	8048	8153	8257	8362	8466	8571	8676	8780	8884	8989	105
416	9093	9198	9302	9406	9511	9615	9719	9824	9928	••32	104
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419	2214	2318	2421	2525	2628	2732	2835	2939	3042	3146	104
420	623249	3353	3456	3559	3663	3766	3869	3973	4076	4179	103
421	4282	4385	4488	4591	4695	4798	4901	5004	5107	5210	103
422	5312	5415	5518	5621	5724	5827	5929	6032	6135	6238	103
423	6340	6443	6546	6648	6751	6853	6956	7058	7161	7263	103
424	7366	7468	7571	7673	7775	7878	7980	8082	8185	8287	102
425	8389	8491	8593	8695	8797	8900	9002	9104	9206	9308	102
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427	630428	0530	0631	0733	0835	0936	1038	1139	1241	1342	102
428	1444	1545	1647	1748	1849	1951	2052	2153	2255	2356	101
429	2457	2559	2660	2761	2862	2963	3064	3165	3266	3367	101
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432	5484	5584	5685	5785	5886	5986	6087	6187	6287	6388	100
433	6488	6588	6688	6789	6889	6989	7089	7189	7290	7390	100
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441	4439	4537	4636	4734	4832	4931	5029	5127	5226	5324	98
442	5422	5521	5619	5717	5815	5913	6011	6110	6208	6306	98
443	6404	6502	6600	6698	6796	6894	6992	7089	7187	7285	98
444	7383	7481	7579	7676	7774	7872	7969	8067	8165	8262	98
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446	9335	9432	9530	9627	9724	9821	9919	••16	•113	•210	97
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448	1278	1375	1472	1569	1666	1762	1859	1956	2053	2150	97
449	2246	2343	2440	2536	2633	2730	2826	2923	3019	3116	97
450	653213	3309	3405	3502	3598	3695	3791	3888	3984	4080	96
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453	6098	6194	6290	6386	6482	6577	6673	6769	6864	5960	96
454	7056	7152	7247	7343	7438	7534	7629	7725	7820	7916	96
455	8011	8107	8202	8298	8393	8488	8584	8679	8774	8870	95
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462	4642	4736	4830	4924	5018	5112	5206	5299	5393	5487	94
463	5581	5675	5769	5862	5956	6050	6143	6237	6331	6424	94
464	6518	6612	6705	6799	6892	6986	7079	7173	7266	7360	94
465	7453	7546	7640	7733	7826	7920	8013	8106	8199	8293	93
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467	9317	9410	9503	9596	9689	9782	9875	9967	••60	•153	93
468	670246	0339	0431	0524	0617	0710	0802	0895	0988	1080	93
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470	672098	2190	2283	2375	2467	2560	2652	2744	2836	2929	92
471	3021	3113	3205	3297	3390	3482	3574	3666	3758	3850	92
472	3942	4034	4126	4218	4310	4402	4494	4586	4677	4769	92
473	4861	4953	5045	5137	5228	5320	5412	5503	5595	5687	92
474	5778	5870	5962	6053	6145	6236	6328	6419	6511	6602	92
475	6694	6785	6876	6968	7059	7151	7242	7333	7424	7516	91
476	7607	7698	7789	7881	7972	8063	8154	8245	8336	8427	91
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494	3727	3815	3903	3991	4078	4166	4254	4342	4430	4517	88
495	4605	4693	4781	4868	4956	5044	5131	5219	5307	5394	88
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506	4151	4236	4322	4408	4494	4579	4665	4751	4837	4922	86
507	5008	5094	5179	5265	5350	5436	5522	5607	5693	5778	86
508	5864	5949	6035	6120	6206	6291	6376	6462	6547	6632	85
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517	3491	3575	3659	3742	3826	3910	3994	4078	4162	4246	84
518	4330	4414	4497	4581	4665	4749	4833	4916	5000	5084	84
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529	3456	3538	3620	3702	3784	3866	3948	4030	4112	4194	82
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533	6727	6809	6890	6972	7053	7134	7216	7297	7379	7460	81
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536	9165	9246	9327	9408	9489	9570	9651	9732	9813	9893	81
537	9974	••55	•136	•217	•298	•378	•459	•540	•621	•702	81
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540	732394	2474	2555	2635	2715	2796	2876	2956	3037	3117	80
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544	5599	5679	5759	5838	5918	5998	6078	6157	6237	6317	80
545	6397	6476	6556	6635	6715	6795	6874	6954	7034	7113	80
546	7193	7272	7352	7431	7511	7590	7670	7749	7829	7908	79
547	7987	8067	8146	8225	8305	8384	8463	8543	8622	8701	79
548	8781	8860	8939	9018	9097	9177	9256	9335	9414	9493	79
549	9572	9651	9731	9810	9889	9968	••47	•126	•205	•284	79
550	740363	0442	0521	0600	0678	0757	0836	0915	0994	1073	79
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552	1939	2018	2096	2175	2254	2332	2411	2489	2568	2647	79
553	2725	2804	2882	2961	3039	3118	3196	3275	3353	3431	78
554	3510	3588	3667	3745	3823	3902	3980	4058	4136	4215	78
555	4293	4371	4449	4528	4606	4684	4762	4840	4919	4997	78
556	5075	5153	5231	5309	5387	5465	5543	5621	5699	5777	78
557	5855	5933	6011	6089	6167	6245	6323	6401	6479	6556	78
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559	7412	7489	7567	7645	7722	7800	7878	7955	8033	8110	78
560	748188	8266	8343	8421	8498	8576	8653	8731	8808	8885	77
561	8963	9040	9118	9195	9272	9350	9427	9504	9582	9659	77
562	9736	9814	9891	9968	••45	•123	•200	•277	•354	•431	77
563	750508	0586	0663	0740	0817	0894	0971	1048	1125	1202	77
564	1279	1356	1433	1510	1587	1664	1741	1818	1895	1972	77
565	2048	2125	2202	2279	2356	2433	2509	2586	2663	2740	77
566	2816	2893	2970	3047	3123	3200	3277	3353	3430	3506	77
567	3583	3660	3736	3813	3889	3966	4042	4119	4195	4272	77
568	4348	4425	4501	4578	4654	4730	4807	4883	[illegible]	5036	76
569	5112	5189	5265	5341	5417	5494	5570	5646	5722	5799	76
570	755875	5951	6027	6103	6180	6256	6332	6408	5484	5560	76
571	6636	6712	6788	6864	6940	7016	7092	7168	7244	7320	76
572	7396	7472	7548	7624	7700	7775	7851	7927	8003	8079	76
573	8155	8230	8306	8382	8458	8533	8609	8685	8761	8836	76
574	8912	8988	9063	9139	9214	9290	9366	9441	9517	9592	76
575	9668	9743	9819	9894	9970	••45	•121	•196	•272	•347	75
576	760422	0498	0573	0649	0724	0799	0875	0950	1025	1101	75
577	1176	1251	1326	1402	1477	1552	1627	1702	1778	1853	75
578	1928	2003	2078	2153	2228	2303	2378	2453	2529	2604	75
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582	4923	4998	5072	5147	5221	5296	5370	5445	5520	5594	75
583	5669	5743	5818	5892	5966	6041	6115	6190	6264	6338	74
584	6413	6487	6562	6636	6710	6785	6859	6933	7007	7082	74
585	7156	7230	7304	7379	7453	7527	7601	7675	7749	7823	74
586	7898	7972	8046	8120	8194	8268	8342	8416	8490	8564	74
587	8638	8712	8786	8860	8934	9008	9082	9156	9230	9303	74
588	9377	9451	9525	9599	9673	9746	9820	9894	9968	••42	74
589	770115	0189	0263	0336	0410	0484	0557	0631	0705	0778	74
590	770852	0926	0999	1073	1146	1220	1293	1367	1440	1514	74
591	1587	1661	1734	1808	1881	1955	2028	2102	2175	2248	73
592	2322	2395	2468	2542	2615	2688	2762	2835	2908	2981	73
593	3055	3128	3201	3274	3348	3421	3494	3567	3640	3713	73
594	3786	3860	3933	4006	4079	4152	4225	4298	4371	4444	73
595	4517	4590	4663	4736	4809	4882	4955	5028	5100	5173	73
596	5246	5319	5392	5465	5538	5610	5683	5756	5829	5902	73
597	5974	6047	6120	6193	6265	6338	6411	6483	6556	6629	73
598	6701	6774	6846	6919	6992	7064	7137	7209	7282	7354	73
599	7427	7499	7572	7644	7717	7789	7862	7934	8006	8079	72
600	778151	8224	8296	8368	8441	8513	8585	8658	8730	8802	72
601	8874	8947	9019	9091	9163	9236	9308	9380	9452	9524	72
602	9596	9669	9741	9813	9885	9957	••29	•101	•173	•245	72
603	780317	0389	0461	0533	0605	0677	0749	0821	0893	0965	72
604	1037	1109	1181	1253	1324	1396	1468	1540	1612	1684	72
605	1755	1827	1899	1971	2042	2114	2186	2258	2329	2401	72
606	2473	2544	2616	2688	2759	2831	2902	2974	3046	3117	72
607	3189	3260	3332	3403	3475	3546	3618	3689	3761	3832	71
608	3904	3975	4046	4118	4189	4261	4332	4403	4475	4546	71
609	4617	4689	4760	4831	4902	4974	5045	5116	5187	5259	71
610	785330	5401	5472	5543	5615	5686	5757	5828	5899	5970	71
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626	6574	6644	6713	6782	6852	6921	6990	7060	7129	7198	69
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633	1404	1472	1541	1609	1678	1747	1815	1884	1952	2021	69
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638	4821	4889	4957	5025	5093	5161	5229	5297	5365	5433	68
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789	7077	7132	7187	7242	7297	7352	7407	7462	7517	7572	55
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791	8176	8231	8286	8341	8396	8451	8506	8561	8615	8670	55
792	8725	8780	8835	8890	8944	8999	9054	9109	9164	9218	55
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797	1458	1513	1567	1622	1676	1731	1785	1840	1894	1948	54
798	2003	2057	2112	2166	2221	2275	2329	2384	2438	2492	54
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800	903090	3144	3199	3253	3307	3361	3416	3470	3524	3578	[illegible]
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803	4716	4770	4824	4878	4932	4986	5040	5094	5148	5202	54
804	5256	5310	5364	5418	5472	5526	5580	5634	5688	5742	54
805	5796	5850	5904	5958	6012	6066	6119	6173	6227	6281	54
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810	908485	8539	8592	8646	8699	8753	8807	8860	891	[illegible]	54
811	9021	9074	9128	9181	9235	9289	9342	9396	944	503	54
812	9556	9610	9663	9716	9770	9823	9877	9930	99	•37	53
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828	8030	8083	8135	8188	8240	8293	8345	8397	8450	8502	52
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835	1686	1738	1790	1842	1894	1946	1998	2050	2102	2154	52
836	2206	2258	2310	2362	2414	2466	2518	2570	2622	2674	52
837	2725	2777	2829	2881	2933	2985	3037	3089	3140	3192	52
838	3244	3296	3348	3399	3451	3503	3555	3607	3658	3710	52
839	3762	3814	3865	3917	3969	4021	4072	4124	4176	4228	52
840	924279	4331	4383	4434	4486	4538	4589	4641	4693	4744	52
841	4796	4848	4899	4951	5003	5054	5106	5157	5209	5261	52
842	5312	5364	5415	5467	5518	5570	5621	5673	5725	5776	52
843	5828	5879	5931	5982	6034	6085	6137	6188	6240	6291	51
844	6342	6394	6445	6497	6548	6600	6651	6702	6754	6805	51
845	6857	6908	6959	7011	7062	7114	7165	7216	7268	7319	51
846	7370	7422	7473	7524	7576	7627	7678	7730	7781	7832	51
847	7883	7935	7986	8037	8088	8140	9191	8242	8293	8345	51
848	8396	8447	8498	8549	8601	8652	8703	8754	8805	8857	51
849	8908	8959	9010	9061	9112	9163	9215	9266	9317	9368	51
850	929419	9470	9521	9572	9623	9674	9725	9776	9827	9879	51
851	9930	9981	••32	••83	•134	•185	•236	•287	•338	•389	51
852	930440	0491	0542	0592	0643	0694	0745	0796	0847	0898	51
853	0949	1000	1051	1102	1153	1204	1254	1305	1356	1407	51
854	1458	1509	1560	1610	1661	1712	1763	1814	1865	1915	51
855	1966	2017	2068	2118	2169	2220	2271	2322	2372	2423	51
856	2474	2524	2575	2626	2677	2727	2778	2829	2874	2930	51
857	2981	3031	3082	3133	3183	3234	3285	3335	3386	3437	51
858	3487	3538	3589	3639	3690	3740	3791	3841	3892	3943	51
859	3993	4044	4094	4145	4195	4246	4296	4347	4397	4448	51
740	934498	4549	4599	4650	4700	4751	4801	4852	4902	4953	50
74[illegible]	5003	5054	5104	5154	5205	5255	5306	5356	5406	5457	50
8[illegible]4	5507	5558	5608	5658	5709	5759	5809	5860	5910	5960	50
863	6011	6061	6111	6162	6212	6262	6313	6363	6413	6463	50
864	6514	6564	6614	6665	6715	6765	6815	6865	6916	6966	50
865	7016	7066	7117	7167	7217	7267	7317	7367	7418	7468	50
866	7518	7568	7618	7668	7718	7769	7819	7869	7919	7969	50
867	4419	8069	8119	8169	8219	8269	8320	8370	8420	8470	50
868	0	8570	8620	8670	8720	8770	8820	8870	8920	8970	50
869	875061 5640	9070	9120	9170	9220	9270	9320	9369	9419	9469	50
870	9[illegible]218	9569	9619	9669	9719	9769	9819	9869	9918	9968	50
871	94[illegible]795	6068	0118	0168	0218	0267	0317	0367	0417	0467	50
872	0[illegible]1	7[illegible]66	0616	0666	0716	0765	0815	0865	0915	0964	50
873	101[illegible]	[illegible]	1114	1163	1213	1263	1313	1362	1412	1462	50
874	1511	1[illegible]	1611	660	1710	1760	1809	1859	1909	1958	50
875	2008	20[illegible]	2107	2157	2207	2256	2306	2355	2405	2455	50
876	2504	2554	2603	2653	2702	2752	2801	2851	2901	2950	50
877	3000	3049	3099	3148	3198	3247	3297	3346	3396	3445	59
878	3495	3544	3593	3643	3692	3742	3791	3841	3890	3939	59
879	3989	4038	4088	4137	4186	4236	4285	4335	4384	4433	59
N.	0	1	2	3	4	5	6	7	8	9	D.

N.	0	1	2	3	4	5	6	7	8	9	D.
880	944483	4532	4581	4631	4680	4729	4779	4828	4877	4927	49
881	4976	5025	5074	5124	5173	5222	5272	5321	5370	5419	49
882	5469	5518	5567	5616	5665	5715	5764	5813	5862	5912	49
883	5961	6010	6059	6108	6157	6207	6256	6305	6354	6403	49
884	6452	6501	5551	6600	6649	6698	6747	6796	6845	6894	49
885	6943	6992	7041	7090	7140	7189	7238	7287	7336	7385	49
886	7434	7483	7532	7581	7630	7679	7728	7777	7826	7875	49
887	7924	7973	8022	8070	8119	8168	8217	8266	8315	8364	49
888	8413	8462	8511	8560	8609	8657	8706	8755	8804	8853	49
889	8902	8951	8999	9048	9097	9146	9195	9244	9292	9341	49
890	949390	9439	9488	9536	585	9634	9683	9731	9780	9829	49
891	9878	9926	9975	••24	••73	•121	•170	•219	•267	•316	49
892	950365	0414	0462	0511	0560	0608	0657	0706	0754	0803	49
893	0851	0900	0949	0997	1046	1095	1143	1192	1240	1289	49
894	1338	1386	1435	1483	1532	1580	1629	1677	1726	1775	49
895	1823	1872	1920	1969	2017	2066	2114	2163	2211	2260	48
896	2308	2356	2405	2453	2502	2550	2599	2647	2696	2744	48
897	2792	2841	2889	2938	2986	3034	3083	3131	3180	3228	48
898	3276	3325	3373	3421	3470	3518	3566	3615	3663	3711	48
899	3760	3808	3856	3905	3953	4001	4049	4098	4146	4194	48
900	954243	4291	4339	4387	4435	4484	4532	4580	4628	4677	48
901	4725	4773	4821	4869	4918	4966	5014	5062	5110	5158	48
902	5207	5255	5303	5351	5399	5447	5495	5543	5592	5640	48
903	5688	5736	5784	5832	5880	5928	5976	6024	6072	6120	48
904	6168	6216	6265	6313	6361	6409	6457	6505	6553	6601	48
905	6649	6697	6745	6793	6840	6888	6936	6984	7032	7080	48
906	7128	7176	7224	7272	7320	7368	7416	7464	7512	7559	48
907	7607	7655	7703	7751	7799	7847	7894	7942	7990	8038	48
908	8086	8134	8181	8229	8277	8325	8373	8421	8468	8516	48
909	8564	8612	8659	8707	8755	8803	8850	8898	8946	8994	48
910	959041	9089	9137	9185	9232	9280	9328	9375	9423	9471	48
911	9518	9566	9614	9661	9709	9757	9804	9852	9900	9947	48
912	9995	••42	••90	•138	•185	•233	•280	•328	•376	•423	48
913	960471	0518	0566	0613	0661	0709	0756	0804	0851	0899	48
914	0946	0994	1041	1089	1136	1184	1231	1279	1326	1374	47
915	1421	1469	1516	1563	1611	1658	1706	1753	1801	1848	47
916	1895	1943	1990	2038	2085	2132	2180	2227	2275	2322	47
917	2369	2417	2464	2511	2559	2606	2653	2701	2748	2795	47
918	2843	2890	2937	2985	3032	3079	3126	3174	3221	3268	47
919	3316	3363	3410	3457	3504	3552	3599	3646	3693	[illegible]	[illegible]
920	963788	3835	3882	3929	3977	4024	4071	4118	4165	4212	47
921	4260	4307	4354	4401	4448	4495	4542	4590	4637	4684	47
922	4731	4778	4825	4872	4919	4966	5013	5061	5108	5155	47
923	5202	5249	5296	5343	5390	5437	5484	5531	5578	5625	47
924	5672	5719	5766	5813	5860	5907	5954	6001	6048	6095	47
925	6142	6189	6236	6283	6329	6376	6423	6470	6517	6564	47
926	6611	6658	6705	6752	6799	6845	6892	6939	6986	7033	47
927	7080	7127	7173	7220	7267	7314	7361	7408	7454	7501	47
928	7548	7595	7642	7688	7735	7782	7829	7875	7922	7969	47
929	8016	8062	8109	8156	8203	8249	8296	8343	8390	8436	47
930	968483	8530	8576	8623	8670	8716	8763	8810	8856	8903	47
931	8950	8996	9043	9090	9136	9183	9229	9276	9323	9369	47
932	9416	9463	9509	9556	9602	9649	9695	9742	9789	9835	47
933	9882	9928	9975	••21	••68	•114	•161	•207	•254	•300	47
934	970347	0393	0440	0486	0533	0579	0626	0672	0719	0765	46
935	0812	0858	0904	0951	0997	1044	1090	1137	1183	1229	46
936	1276	1322	1369	1415	1461	1508	1554	1601	1647	1693	46
937	1740	1786	1832	1879	1925	1971	2018	2064	2110	2157	46
938	2203	2249	2295	2342	2388	2434	2481	2527	2573	2619	46
939	2666	2712	2758	2804	2851	2897	2943	2989	3035	3082	46
N	0	1	2	3	4	5	6	7	8	9	D.

N.	0	1	2	3	4	5	6	7	8	9	D.
940	973128	3174	3220	3266	3313	3359	3405	3451	3497	3543	46
941	3590	3636	3682	3728	3774	3820	3866	3913	3959	4005	46
942	4051	4097	4143	4189	4235	4281	4327	4374	4420	4466	46
943	4512	4558	4604	4650	4696	4742	4788	4834	4880	4926	46
944	4972	5018	5064	5110	5156	5202	5248	5294	5340	5386	46
945	5432	5478	5524	5570	5616	5662	5707	5753	5799	5845	46
946	5891	5937	5983	6029	6075	6121	6167	6212	6258	6304	46
947	6350	6396	6442	6488	6533	6579	6625	6671	6717	6763	46
948	6808	6854	6900	6946	6992	7037	7083	7129	7175	7220	46
949	7266	7312	7358	7403	7449	7495	7541	7586	7632	7678	46
950	977724	7769	7815	7861	7906	7952	7998	8043	8089	8135	46
951	8181	8226	8272	8317	8363	8409	8454	8500	8546	8591	46
952	8637	8683	8728	8774	8819	8865	8911	8956	9002	9047	46
953	9093	9138	9184	9230	9275	9321	9366	9412	9457	9503	46
954	9548	9594	9639	9685	9730	9776	9821	9867	9912	9958	46
955	980003	0049	0094	0140	0185	0231	0276	0322	0367	0412	45
956	0458	0503	0549	0594	0640	0685	0730	0776	0821	0867	45
957	0912	0957	1003	1048	1093	1139	1184	1229	1275	1320	45
958	1366	1411	1456	1501	1547	1592	1637	1683	1728	1773	45
959	1819	1864	1909	1954	2000	2045	2090	2135	2181	2226	45
960	982271	2316	2362	2407	2452	2497	2543	2588	2633	2678	45
961	2723	2769	2814	2859	2904	2949	2994	3040	3085	3130	45
962	3175	3220	3265	3310	3356	3401	3446	3491	3536	3581	45
963	3626	3671	3716	3762	3807	3852	3897	3942	3987	4032	45
964	4077	4122	4167	4212	4257	4302	4347	4392	4437	4482	45
965	4527	4572	4617	4662	4707	4752	4797	4842	4887	4932	45
966	4977	5022	5067	5112	5157	5202	5247	5292	5337	5382	45
967	5426	5471	5516	5561	5606	5651	5696	5741	5786	5830	45
968	5875	5920	5965	6010	6055	6100	6144	6189	6234	6279	45
969	6324	6369	6413	6458	6503	6548	6593	6637	6682	6727	45
970	986772	6817	6861	6906	6951	6996	7040	7085	7130	7175	45
971	7219	7264	7309	7353	7398	7443	7488	7532	7577	7622	45
972	7666	7711	7756	7800	7845	7890	7934	7979	8024	8068	45
973	8113	8157	8202	8247	8291	8336	8381	8425	8470	8514	45
974	8559	8604	8648	8693	8737	8782	8826	8871	8916	8960	45
975	9005	9049	9094	9138	9183	9227	9272	9316	9361	9405	45
976	9450	9494	9539	9583	9628	9672	9717	9761	9806	9850	44
7	9895	9939	9983	••28	••72	•117	•161	•206	•250	•294	44
	990339	0383	0428	0472	0516	0561	0605	0650	0694	0738	44
	0783	0827	0871	0916	0960	1004	1049	1093	1137	1182	44
	991226	1270	1315	1359	1403	1448	1492	1536	1580	1625	44
	1669	1713	1758	1802	1846	1890	1935	1979	2023	2067	44
	2111	2156	2200	2244	2288	2333	2377	2421	2465	2509	44
3	2554	2598	2642	2686	2730	2774	2819	2863	2907	2951	44
4	2995	3039	3083	3127	3172	3216	3260	3304	3348	3392	44
85	3436	3480	3524	3568	3613	3657	3701	3745	3789	3833	44
986	3877	3921	3965	4009	4053	4097	4141	4185	4229	4273	44
987	4317	4361	4405	4449	4493	4537	4581	4625	4669	4713	44
988	4757	4801	4845	4889	4933	4977	5021	5065	5108	5152	44
989	5196	5240	5284	5328	5372	5416	5460	5504	5547	5591	44
990	995635	5679	5723	5767	5811	5854	5898	5942	5986	6030	44
991	6074	6117	6161	6205	6249	6293	6337	6380	6424	6468	44
992	6512	6555	6599	6643	6687	6731	6774	6818	6862	6906	44
993	6949	6993	7037	7080	7124	7168	7212	7255	7299	7343	44
994	7386	7430	7474	7517	7561	7605	7648	7692	7736	7779	44
995	7823	7867	7910	7954	7998	8041	8085	8129	8172	8216	44
996	8259	8303	8347	8390	8434	8477	8521	8564	8608	8652	44
997	8695	8739	8782	8826	8869	8913	8956	9000	9043	9087	44
998	9131	9174	9218	9261	9305	9348	9392	9435	9479	9522	44
999	9565	9609	9652	9696	9739	9783	9826	9870	9913	9957	43
N.	0	1	2	3	4	5	6	7	8	9	D.

A TABLE

OF

LOGARITHMIC

SINES AND TANGENTS

FOR EVERY

DEGREE AND MINUTE

OF THE QUADRANT.

Remark. The minutes in the left-hand column of each page, increasing downwards, belong to the degrees at the top; and those increasing upwards, in the right-hand column, belong to the degrees below.

M.	Sine	D.	Cosine	D.	Tang.	D	Cotang.	
0			10·000000		0·000000		Infinite.	60
1	6·463726	5017·17	000000	·00	6·463726	5017·17	13·536274	59
2	764756	2934·85	000000	·00	764756	2934·83	235244	58
3	940847	2082·31	000000	·00	940847	2082·31	059153	57
4	7·065786	1615·17	000000	·00	7·065786	1615·17	12·934214	56
5	162696	1319·68	000000	·00	162696	1319·69	837304	55
6	241877	1115·75	9·999999	·01	241878	1115·78	758122	54
7	308824	966·53	999999	·01	308825	996·53	691175	53
8	366816	852·54	999999	·01	366817	852·54	633183	52
9	417968	762·63	999999	·01	417970	762·63	582030	51
10	463725	689·88	999998	·01	463727	689·88	536273	50
11	7·505118	629·81	9·999998	·01	7·505120	629·81	12·494880	49
12	542906	579·36	999997	·01	542909	579·33	457091	48
13	577668	536·41	999997	·01	577672	536·42	422328	47
14	609853	499·38	999996	·01	609857	499·39	390143	46
15	639816	467·14	999996	·01	639820	467·15	360180	45
16	667845	438·81	999995	·01	667849	438·82	332151	44
17	694173	413·72	999995	·01	694179	413·73	305821	43
18	718997	391·35	999994	·01	719004	391·36	280997	42
19	742477	371·27	999993	·01	742484	371·28	257516	41
20	764754	353·15	999993	·01	764761	353·17	235239	40
21	7·785943	336·72	9·999992	·01	7·785951	336·73	12·214049	39
22	806146	321·75	999991	·01	806155	321·76	193845	38
23	825451	308·05	999990	·01	825460	308·06	174540	37
24	843934	295·47	999989	·02	843944	295·49	156056	36
25	861662	283·88	999988	·02	861674	283·90	138326	35
26	878695	273·17	999988	·02	878708	273·18	121292	34
27	895085	263·23	999987	·02	895099	263·25	104901	33
28	910879	253·99	999986	·02	910894	254·01	089106	32
29	926119	245·38	999985	·02	926134	245·40	073866	31
30	940842	237·33	999983	·02	940858	237·35	059142	30
31	7·955082	229·80	9·999982	·02	7·955100	229·81	12·044900	29
32	968870	222·73	999981	·02	968889	222·75	031111	28
33	982233	216·08	999980	·02	982253	216·10	017747	27
34	995198	209·81	999979	·02	995219	209·83	004781	26
35	8·007787	203·90	999977	·02	8·007809	203·92	11·992191	25
36	020021	198·31	999976	·02	020045	198·33	979955	24
37	031919	193·02	999975	·02	031945	193·05	968055	23
38	043501	188·01	999973	·02	043527	188·03	956473	22
39	054781	183·25	999972	·02	054809	183·27	945191	21
40	065776	178·72	999971	·02	065806	178·74	934194	20
41	8·076500	174·41	9·999969	·02	8·076531	174·44	11·923469	19
42	086965	170·31	999968	·02	086997	170·34	913003	18
43	097183	166·39	999966	·02	097217	166·42	902783	17
44	107167	162·65	999964	·03	107202	162·68	892797	16
45	116926	159·08	999963	·03	116963	159·10	883037	15
46	126471	155·66	999961	·03	126510	155·68	873490	14
47	135810	152·38	999959	·03	135851	152·41	864149	13
48	144953	149·24	999958	·03	144996	149·27	855004	12
49	153907	146·22	999955	·03	153952	146·27	846048	11
50	162681	143·33	999954	·03	162727	143·36	837273	10
51	8·171280	140·54	9·999952	·03	8·171328	140·57	11·828672	9
52	179713	137·86	999950	·03	179763	137·90	820237	8
53	187985	135·29	999948	·03	188036	135·32	811964	7
54	196102	132·80	999946	·03	196156	132·84	803844	6
55	204070	130·41	999944	·03	204126	130·44	795874	5
56	211895	128·10	999942	·04	211953	128·14	788047	4
57	219581	125·87	999940	·04	219641	125·90	780359	3
58	227134	123·72	999938	·04	227195	123·76	772805	2
59	234557	121·64	999936	·04	234621	121·68	765379	1
60	241855	119·63	999934	·04	241921	119·67	758079	0
	Cosine	D.	Sine		Cotang.	D.	Tang.	M.

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	8·241855	119·63	9·999934	·04	8·241921	119·67	11·758079	60
1	249033	117·68	999932	·04	249102	117·72	750898	59
2	256094	115·80	999929	·04	256165	115·84	743835	58
3	263042	113·98	999927	·04	263115	114·02	736885	57
4	269881	112·21	999925	·04	269956	112·25	730044	56
5	276614	110·50	999922	·04	276691	110·54	723309	55
	283243	108·83	999920	·04	283323	108·87	716677	54
	289773	107·21	999918	·04	289856	107·26	710144	53
	296207	105·65	999915	·04	296292	105·70	703708	52
	302546	104·13	999913	·04	302634	104·18	697366	51
1	308794	102·66	999910	·04	308884	102·70	691116	50
11	8·314904	101·22	9·999907	·04	8·315046	101·26	11·684954	49
12	321027	99·82	999905	·04	321122	99·87	678878	48
13	327016	98·47	999902	·04	327114	98·51	672886	47
14	332924	97·14	999899	·05	333025	97·19	666975	46
15	338753	95·86	999897	·05	338856	95·90	661144	45
16	344504	94·60	999894	·05	344610	94·65	655390	44
17	350181	93·38	999891	·05	350289	93·43	649711	43
18	355783	92·19	999888	·05	355895	92·24	644105	42
19	361315	91·03	999885	·05	361430	91·08	638570	41
20	366777	89·90	999882	·05	366895	89·95	633105	40
21	8·372171	88·80	9·999879	·05	8·372292	88·85	11·627708	39
22	377499	87·72	999876	·05	377622	87·77	622378	38
23	382762	86·67	999873	·05	382889	86·72	617111	37
24	387962	85·64	999870	·05	388092	85·70	611908	36
25	393101	84·64	999867	·05	393234	84·70	606766	35
26	398179	83·66	999864	·05	398315	83·71	601685	34
27	403199	82·71	999861	·05	403338	82·76	596662	33
28	408161	81·77	999858	·05	408304	81·82	591696	32
29	413068	80·86	999854	·05	413213	80·91	586787	31
30	417919	79·96	999851	·06	418068	80·02	581932	30
31	8·422717	79·09	9·999848	·06	8·422869	79·14	11·577131	29
32	427462	78·23	999844	·06	427618	78·30	572382	28
33	432156	77·40	999841	·06	432315	77·45	567685	27
34	436800	76·57	999838	·06	436962	76·63	563038	26
35	441394	75·77	999834	·06	441560	75·83	558440	25
36	445941	74·99	999831	·06	446110	75·05	553890	24
37	450440	74·22	999827	·06	450613	74·28	549387	23
38	454893	73·46	999823	·06	455070	73·52	544930	22
39	459301	72·73	999820	·06	459481	72·79	540519	21
40	463665	72·00	999816	·06	463849	72·06	536151	20
41	8·467985	71·29	9·999812	·06	8·468172	71·35	11·531828	19
42	472263	70·60	999809	·06	472454	70·66	527546	18
43	476498	69·91	999805	·06	476693	69·98	523307	17
44	480693	69·24	999801	·06	480892	69·31	519108	16
45	484848	68·59	999797	·07	485050	68·65	514950	15
46	488963	67·94	999793	·07	489170	68·01	510830	14
47	493040	67·31	999790	·07	493250	67·38	506750	13
48	497078	66·69	999786	·07	497293	66·76	502707	12
49	501080	66·08	999782	·07	501298	56·15	498702	11
50	505045	65·48	999778	·07	505267	65·55	494733	10
51	8·508974	64·89	9·999774	·07	8·509200	64·96	11·490800	9
52	512867	64·31	999769	·07	513098	64·39	486902	8
53	516726	63·75	999765	·07	516961	63·82	483039	7
54	520551	63·19	999761	·07	520790	63·26	479210	6
55	524343	62·64	999757	·07	524586	62·72	475414	5
56	528102	62·11	999753	·07	528349	62·18	471651	4
57	531828	61·58	999748	·07	532080	61·65	467920	3
58	535523	61·06	999744	·07	535779	61·13	464221	2
59	539186	60·55	999740	·07	539447	60·62	460553	1
60	542819	60·04	999735	·07	543084	60·12	456916	0
	Cosine	D.	Sine		Cotang.	D.	Tang	

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	8·542819	60·04	9·999735	·07	8·543084	60·12	11·456916	60
1	546422	59·55	999731	·07	546691	59·62	453309	59
2	549995	59·06	999726	·07	550268	59·14	449732	58
3	553539	58·58	999722	·08	553817	58·66	446183	57
4	557054	58·11	999717	·08	557336	58·19	442664	56
5	560540	57·65	999713	·08	560828	57·73	439172	55
6	563999	57·19	999708	·08	564291	57·27	435709	54
7	567431	56·74	999704	·08	567727	56·82	432273	53
8	570836	56·30	999699	·08	571137	56·38	428863	52
9	574214	55·87	999694	·08	574520	55·95	425480	51
10	577566	55·44	999689	·08	577877	55·52	422123	50
11	8·580892	55·02	9·999685	·08	8·581208	55·10	11·418792	49
12	584193	54·60	999680	·08	584514	54·68	415486	48
13	587469	54·19	999675	·08	587795	54·27	412205	47
14	590721	53·79	999670	·08	591051	53·87	408949	46
15	593948	53·39	999665	·08	594283	53·47	405717	45
16	597152	53·00	999660	·08	597492	53·08	402508	44
17	600332	52·61	999655	·08	600677	52·70	399323	43
18	603489	52·23	999650	·08	603839	52·32	396161	42
19	606623	51·86	999645	·09	606978	51·94	393022	41
20	609734	51 49	999640	·09	610094	51·58	389906	40
21	8·612823	51·12	9·999635	·09	8·613189	51·21	11·386811	39
22	615891	50·76	999629	·09	616262	50·85	383738	38
23	618937	50·41	999624	·09	619313	50·50	380687	37
24	621962	50·06	999619	·09	622343	50·15	377657	36
25	624965	49·72	999614	·09	625352	49·81	374648	35
26	627948	49·38	999608	·09	628340	49·47	371660	34
27	630911	49·04	999603	·09	631308	49·13	368692	33
28	633854	48·71	999597	·09	634256	48·80	365744	32
29	636776	48·39	999592	·09	637184	48·48	362816	31
30	639680	48·06	999586	·09	640093	48·16	359907	30
31	8·642563	47·75	9·999581	·09	8·642982	47·84	11·357018	29
32	645428	47·43	999575	·09	645853	47·53	354147	28
33	648274	47·12	999570	·09	648704	47·22	351296	27
34	651102	46·82	999564	·09	651537	46·91	348463	26
35	653911	46·52	999558	·10	654352	46·61	345648	25
36	656702	46·22	999553	·10	657149	46·31	342851	24
37	659475	45·92	999547	·10	659928	46·02	340072	23
38	662230	45·63	999541	·10	662689	45·73	337311	22
39	664968	45·35	999535	·10	665433	45·44	334567	21
40	667689	45·06	999529	·10	668160	45·26	331840	20
41	8·670393	44·79	9·999524	·10	8·670870	44·88	11·329130	19
42	673080	44·51	999518	·10	673563	44·61	326437	18
43	675751	44·24	999512	·10	676239	44·34	323761	17
44	678405	43·97	999506	·10	678900	44·17	321100	16
45	681043	43·70	999500	·10	681544	43·80	318456	15
46	683665	43·44	999493	·10	684172	43·54	315828	14
47	686272	43·18	999487	·10	686784	43·28	313216	13
48	688863	42·92	999481	·10	589381	43·03	310619	12
49	691438	42·67	999475	·10	691963	42·77	308037	11
50	693998	42·42	999469	·10	694529	42·52	305471	10
51	8 696543	42·17	9·999463	·11	8·697081	42·28	11 302919	9
51	699073	41·92	999456	·11	699617	42·03	300383	8
51	701589	41·68	999450	·11	702139	41·79	297861	7
54	704090	41·44	999443	·11	704646	41·55	295354	6
55	706577	41·21	999437	·11	707140	41·32	292860	5
56	709049	40·97	999431	·11	709618	41·08	290382	4
57	711507	40·74	999424	·11	712083	40·85	287917	3
58	713952	40·51	999418	·11	714534	40·62	285465	2
59	716383	40·29	999411	·11	716972	40·40	283028	1
60	718800	40·06	999404	·11	719396	40·17	280604	0
	Cosine	D.	Sine		Cotang.	D.	Tang.	M.

(87 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	8·718800	40·06	9·999404	·11	8·719396	40·17	11·280604	60
1	721204	39·84	999398	·11	721806	39·95	278194	59
2	723595	39·62	999391	·11	724204	39·74	275796	58
3	725972	39·41	999384	·11	726588	39·52	273412	57
4	728337	39·19	999378	·11	728959	39·30	271041	56
5	730688	38·98	999371	·11	731317	39·09	268683	55
6	733027	38·77	999364	·12	733663	38·89	266337	54
7	735354	38·57	999357	·12	735996	38·68	264004	53
8	737667	38·36	999350	·12	738317	38·48	261683	52
9	739969	38·16	999343	·12	740626	38·27	259374	51
10	742259	37·96	999336	·12	742922	38·07	257078	50
11	8·744536	37·76	9·999329	·12	8·745207	37·87	11·254793	49
12	746802	37·56	999322	·12	747479	37·68	252521	48
13	749055	37·37	999315	·12	749740	37·49	250260	47
14	751297	37·17	999308	·12	751989	37·29	248011	46
15	753528	36·98	999301	·12	754227	37·10	245773	45
16	755747	36·79	999294	·12	756453	36·92	243547	44
17	757955	36·61	999286	·12	758668	36·73	241332	43
18	760151	36·42	999279	·12	760872	36·55	239128	42
19	762337	36·24	999272	·12	763065	36·36	236935	41
20	764511	36·06	999265	·12	765246	36·18	234754	40
21	8·766675	35·88	9·999257	·12	8·767417	36·00	11·232583	39
22	768828	35·70	999250	·13	769578	35·83	230422	38
23	770970	35·53	999242	·13	771727	35·65	228273	37
24	773101	35·35	999235	·13	773866	35·48	226134	36
25	775223	35·18	999227	·13	775995	35·31	224005	35
26	777333	35·01	999220	·13	778114	35·14	221886	34
27	779434	34·84	999212	·13	780222	34·97	219778	33
28	781524	34·67	999205	·13	782320	34·80	217680	32
29	783605	34·51	999197	·13	784408	34·64	215592	31
30	785675	34·31	999189	·13	786486	34·47	213514	30
31	8·787736	34·18	9·999181	·13	8·788554	34·31	11·211446	29
32	789787	34·02	999174	·13	790613	34·15	209387	28
33	791828	33·86	999166	·13	792662	33·99	207338	27
34	793859	33·70	999158	·13	794701	33·83	205299	26
35	795881	33·54	999150	·13	796731	33·68	203269	25
36	797894	33·39	999142	·13	798752	33·52	201248	24
37	799897	33·23	999134	·13	800763	33·37	199237	23
38	801892	33·08	999126	·13	802765	33·22	197235	22
39	803876	32·93	999118	·13	804758	33·07	195242	21
40	805852	32·78	999110	·13	806742	32·92	193258	20
41	8·807819	32·63	9·999102	·13	8·808717	32·78	11·191283	19
42	809777	32·49	999094	·14	810683	32·62	189317	18
43	811726	32·34	999086	·14	812641	32·48	187359	17
44	813667	32·19	999077	·14	814589	32·33	185411	16
45	815599	32·05	999069	·14	816529	32·19	183471	15
46	817522	31·91	999061	·14	818461	32·05	181539	14
47	819436	31·77	999053	·14	820384	31·91	179616	13
48	821343	31·63	999044	·14	822298	31·77	177702	12
49	823240	31·49	999036	·14	824205	31·63	175795	11
50	825130	31·35	999027	·14	826103	31·50	173897	10
51	8·827011	31·22	9·999019	·14	8·827992	31·36	11·172008	9
52	828884	31·08	999010	·14	829874	31·23	170126	8
53	830749	30·95	999002	·14	831748	31·10	168252	7
54	832607	30·82	998993	·14	833613	30·96	166387	6
55	834456	30·69	998984	·14	835471	30·83	164529	5
56	836297	30·56	998976	·14	837321	30·70	162679	4
57	838130	30·43	998967	·15	839163	30·57	160837	3
58	839956	30·30	998958	·15	840998	30·45	159002	2
59	841774	30·17	998950	·15	842825	30·32	157175	1
60	843585	30·00	998941	·15	844644	30·19	155356	0
	Cosine	D.	Sine		Cotang.	D.	Tang.	M.

(86 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D	Cotang.	
0			10·000000		0·000000		Infinite.	60
1	6·463726	5017·17	000000	·00	6·463726	5017·17	13·536274	59
2	764756	2934·85	000000	·00	764756	2934·83	235244	58
3	940847	2082·31	000000	·00	940847	2082·31	059153	57
4	7·065786	1615·17	000000	·00	7·065786	1615·17	12·934214	56
5	162696	1319·68	000000	·00	162696	1319·69	837304	55
6	241877	1115·75	9·999999	·01	241878	1115·78	758122	54
7	308824	966·53	999999	·01	308825	996·53	691175	53
8	366816	852·54	999999	·01	366817	852·54	633183	52
9	417968	762·63	999999	·01	417970	762·63	582030	51
10	463725	689·88	999998	·01	463727	689·88	536273	50
11	7·505118	529·81	9·999998	·01	7·505120	629·81	12·494880	49
12	542906	579·36	999997	·01	542909	579·33	457091	48
13	577668	536·41	999997	·01	577672	536·42	422328	47
14	609853	499·38	999996	·01	609857	499·39	390143	46
15	639816	467·14	999996	·01	639820	467·15	360180	45
16	667845	438·81	999995	·01	667849	438·82	332151	44
17	694173	413·72	999995	·01	694179	413·73	305821	43
18	718997	391·35	999994	·01	719004	391·36	280997	42
19	742477	371·27	999993	·01	742484	371·28	257516	41
20	764754	353·15	999993	·01	764761	351·25	235239	40
21	7·785943	336·72	9·999992	·01	7·785951	336·73	12·214049	39
22	806146	321·75	999991	·01	806155	321·76	193845	38
23	825451	308·05	999990	·01	825460	308·06	174540	37
24	843934	295·47	999989	·02	843944	295·49	156056	36
25	861662	283·88	999988	·02	861674	283·90	138326	35
26	878695	273·17	999988	·02	878708	273·18	121292	34
27	895085	263·23	999987	·02	895099	263·25	104901	33
28	910879	253·99	999986	·02	910894	254·01	089106	32
29	926119	245·38	999985	·02	926134	245·40	073866	31
30	940842	237·33	999983	·02	940858	237·35	059142	30
31	7·955082	229·80	9·999982	·02	7·955100	229·81	12·044900	29
32	968870	222·73	999981	·02	968889	222·75	031111	28
33	982233	216·08	999980	·02	982253	216·10	017747	27
34	995198	209·81	999979	·02	995219	209·83	004781	26
35	8·007787	203·90	999977	·02	8·007809	203·92	11·992191	25
36	020021	198·31	999976	·02	020045	198·33	979955	24
37	031919	193·02	999975	·02	031945	193·05	968055	23
38	043501	188·01	999973	·02	043527	188·03	956473	22
39	054781	183·25	999972	·02	054809	183·27	945191	21
40	065776	178·72	999971	·02	065806	178·74	934194	20
41	8·076500	174·41	9·999969	·02	8·076531	174·44	11·923469	19
[illegible]	086965	170·31	999968	·02	086997	170·34	913003	18
[illegible]	097183	166·39	999966	·02	097217	166·42	902783	17
[illegible]	107167	162·65	999964	·03	107202	162·68	892797	16
[illegible]	116926	159·08	999963	·03	116963	159·10	883037	15
[illegible]	126471	155·66	999961	·03	126510	155·68	873490	14
[illegible]	135810	152·38	999959	·03	135851	152·41	864149	13
[illegible]	144953	149·24	999958	·03	144996	149·27	855004	12
[illegible]	153907	146·22	999955	·03	153952	146·27	846048	11
[illegible]	162681	143·33	999954	·03	162727	143·36	837273	10
[illegible]	8·171280	140·54	9·999952	·03	8·171328	140·57	11·828672	9
[illegible]	179713	137·86	999950	·03	179763	137·90	820237	8
[illegible]	187985	135·29	999948	·03	188036	135·32	811964	7
4	196102	132·80	999946	·03	196156	132·84	803844	6
55	204070	130·41	999944	·03	204126	130·44	795874	5
56	211895	128·10	999942	·04	211953	128·14	788047	4
57	219581	125·87	999940	·04	219641	125·90	780359	3
58	227134	123·72	999938	·04	227195	123·76	772805	2
59	234557	121·64	999936	·04	234621	121·68	765379	1
60	241855	119·63	999934	·04	241921	119·67	758079	0
	Cosine	D.	Sine		Cotang.	D.	Tang.	M.

(89 DEGREES.)

SINES AND TANGENTS. (1 DEGREE.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	8·241855	119·63	9·999934	·04	8·241921	119·67	11·758079	60
1	249033	117·68	999932	·04	249102	117·72	750898	59
2	256094	115·80	999929	·04	256165	115·84	743835	58
3	263042	113·98	999927	·04	263115	114·02	736885	57
4	269881	112·21	999925	·04	269956	112·25	730044	56
5	276614	110·50	999922	·04	276691	110·54	723309	55
6	283243	108·83	999920	·04	283323	108·87	716677	54
7	289773	107·21	999918	·04	289856	107·26	710144	53
8	296207	105·65	999915	·04	296292	105·70	703708	52
9	302546	104·13	999913	·04	302634	104·18	697366	51
10	308794	102·66	999910	·04	308884	102·70	691116	50
11	8·314904	101·22	9·999907	·04	8·315046	101·26	11·684954	49
12	321027	99·82	999905	·04	321122	99·87	678878	48
13	327016	98·47	999902	·04	327114	98·51	672886	47
14	332924	97·14	999899	·05	333025	97·19	666975	46
15	338753	95·86	999897	·05	338856	95·90	661144	45
16	344504	94·60	999894	·05	344610	94·65	655390	44
17	350181	93·38	999891	·05	350289	93·43	649711	43
18	355783	92·19	999888	·05	355895	92·24	644105	42
19	361315	91·03	999885	·05	361430	91·08	638570	41
20	366777	89·90	999882	·05	366895	89·95	633105	40
21	8·372171	88·80	9·999879	·05	8·372292	88·85	11·627708	39
22	377499	87·72	999876	·05	377622	87·77	622378	38
23	382762	86·67	999873	·05	382889	86·72	617111	37
24	387962	85·64	999870	·05	388092	85·70	611908	36
25	393101	84·64	999867	·05	393234	84·70	606766	35
26	398179	83·66	999864	·05	398315	83·71	601685	34
27	403199	82·71	999861	·05	403338	82·76	596662	33
28	408161	81·77	999858	·05	408304	81·82	591696	32
29	413068	80·86	999854	·05	413213	80·91	586787	31
30	417919	79·96	999851	·06	418068	80·02	581932	30
31	8·422717	79·09	9·999848	·06	8·422869	79·14	11·577131	29
32	427462	78·23	999844	·06	427618	78·30	572382	28
33	432156	77·40	999841	·06	432315	77·45	567685	27
34	436800	76·57	999838	·06	436962	76·63	563038	26
35	441394	75·77	999834	·06	441560	75·83	558440	25
36	445941	74·99	999831	·06	446110	75·05	553890	24
37	450440	74·22	999827	·06	450613	74·28	549387	23
38	454893	73·46	999823	·06	455070	73·52	544930	22
39	459301	72·73	999820	·06	459481	72·79	540519	21
40	463665	72·00	999816	·06	463849	72·06	536151	20
41	8·467985	71·29	9·999812	·06	8·468172	71·35	11·531828	19
42	472263	70·60	999809	·06	472454	70·66	527546	18
43	476498	69·91	999805	·06	476693	69·98	523307	17
44	480693	69·24	999801	·06	480892	69·31	519108	16
45	484848	68·59	999797	·07	485050	68·65	514950	15
46	488963	67·94	999793	·07	489170	68·01	510830	14
47	493040	67·31	999790	·07	493250	67·38	506750	13
48	497078	66·69	999786	·07	497293	66·76	502707	12
49	501080	66·08	999782	·07	501298	56·15	498702	11
50	505045	65·48	999778	·07	505267	65·55	494733	10
51	8·508974	64·89	9·999774	·07	8·509200	64·96	11·490800	9
52	512867	64·31	999769	·07	513098	64·39	486902	8
53	516726	63·75	999765	·07	516961	63·82	483039	7
54	520551	63·19	999761	·07	520790	63·26	479210	6
55	524343	62·64	999757	·07	524586	62·72	475414	5
56	528102	62·11	999753	·07	528349	62·18	471651	4
57	531828	61·58	999748	·07	532080	61·65	467920	3
58	535523	61·06	999744	·07	535779	61·13	464221	2
59	539186	60·55	999740	·07	539447	60·62	460553	1
60	542819	60·04	999735	·07	543084	60·12	456916	0
	Cosine	D.	Sine		Cotang.	D.	Tang.	

(88 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	8·542819	60·04	9·999735	·07	8·543084	60·12	11·456916	60
1	546422	59·55	999731	·07	546691	59·62	453309	59
2	549995	59·06	999726	·07	550268	59·14	449732	58
3	553539	58·58	999722	·08	553817	58·66	446183	57
4	557054	58·11	999717	·08	557336	58·19	442664	56
5	560540	57·65	999713	·08	560828	57·73	439172	55
6	563999	57·19	999708	·08	564291	57·27	435709	54
7	567431	56·74	999704	·08	567727	56·82	432273	53
8	570836	56·30	999699	·08	571137	56·38	428863	52
9	574214	55·87	999694	·08	574520	55·95	425480	51
10	577566	55·44	999689	·08	577877	55·52	422123	50
11	8·580892	55·02	9·999685	·08	8·581208	55·10	11·418792	49
12	584193	54·60	999680	·08	584514	54·68	415486	48
13	587469	54·19	999675	·08	587795	54·27	412205	47
14	590721	53·79	999670	·08	591051	53·87	408949	46
15	593948	53·39	999665	·08	594283	53·47	405717	45
16	597152	53·00	999660	·08	597492	53·08	402508	44
17	600332	52·61	999655	·08	600677	52·70	399323	43
18	603489	52·23	999650	·08	603839	52·32	396161	42
19	606623	51·86	999645	·09	606978	51·94	393022	41
20	609734	51·49	999640	·09	610094	51·58	389906	40
21	8·612823	51·12	9·999635	·09	8·613189	51·21	11·386811	39
22	615891	50·76	999629	·09	616262	50·85	383738	38
23	618937	50·41	999624	·09	619313	50·50	380687	37
24	621962	50·06	999619	·09	622343	50·15	377657	36
25	624965	49·72	999614	·09	625352	49·81	374648	35
26	627948	49·38	999608	·09	628340	49·47	371660	34
27	630911	49·04	999603	·09	631308	49·13	368692	33
28	633854	48·71	999597	·09	634256	48·80	365744	32
29	636776	48·39	999592	·09	637184	48·48	362816	31
30	639680	48·06	999586	·09	640093	48·16	359907	30
31	8·642563	47·75	9·999581	·09	8·642982	47·84	11·357018	29
32	645428	47·43	999575	·09	645853	47·53	354147	28
33	648274	47·12	999570	·09	648704	47·22	351296	27
34	651102	46·82	999564	·09	651537	46·91	348463	26
35	653911	46·52	999558	·10	654352	46·61	345648	25
36	656702	46·22	999553	·10	657149	46·31	342851	24
37	659475	45·92	999547	·10	659928	46·02	340072	23
38	662230	45·63	999541	·10	662689	45·73	337311	22
39	664968	45·35	999535	·10	665433	45·44	334567	21
40	667689	45·06	999529	·10	668160	45·26	331840	20
41	8·670393	44·79	9·999524	·10	8·670870	44·88	11·329130	19
42	673080	44·51	999518	·10	673563	44·61	326437	18
43	675751	44·24	999512	·10	676239	44·34	323761	17
44	678405	43·97	999506	·10	678900	44·17	321100	16
45	681043	43·70	999500	·10	681544	43·80	318456	15
46	683665	43·44	999493	·10	684172	43·54	315828	14
47	686272	43·18	999487	·10	686784	43·28	313216	13
48	688863	42·92	999481	·10	589381	43·03	310619	12
49	691438	42·67	999475	·10	691963	42·77	308037	11
50	693998	42·42	999469	·10	694529	42·52	305471	10
51	8 696543	42·17	9·999463	·11	8·697081	42·28	11 302919	9
52	699073	41·92	999456	·11	699617	42·03	300383	8
53	701589	41·68	999450	·11	702139	41·79	297861	7
54	704090	41·44	999443	·11	704646	41·55	295354	6
55	706577	41·21	999437	·11	707140	41·32	292860	5
56	709049	40·97	999431	·11	709618	41·08	290382	4
57	711507	40·74	999424	·11	712083	40·85	287917	3
58	713952	40·51	999418	·11	714534	40·62	285465	2
59	716383	40·29	999411	·11	716972	40·40	283028	1
60	718800	40·06	999404	·11	719396	40·17	280604	0
	Cosine	D.	Sine		Cotang.	D.	Tang.	M.

(87 DEGREES.)

SINES AND TANGENTS (3 DEGREES,

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	8·718800	40·06	9·999404	·11	8·719396	40·17	11·280604	60
1	721204	39·84	999398	·11	721806	39·95	278194	59
2	723595	39·62	999391	·11	724204	39·74	275796	58
3	725972	39·41	999384	·11	726588	39·52	273412	57
4	728337	39·19	999378	·11	728959	39·30	271041	56
5	730688	38·98	999371	·11	731317	39·09	268683	55
6	733027	38·77	999364	·12	733663	38·89	266337	54
7	735354	38·57	999357	·12	735996	38·68	264004	53
8	737667	38·36	999350	·12	738317	38·48	261683	52
9	739969	38·16	999343	·12	740626	38·27	259374	51
10	742259	37·96	999336	·12	742922	38·07	257078	50
11	8·744536	37·76	9·999329	·12	8·745207	37·87	11·254793	49
12	746802	37·56	999322	·12	747479	37·68	252521	48
13	749055	37·37	999315	·12	749740	37·49	250260	47
14	751297	37·17	999308	·12	751989	37·29	248011	46
15	753528	36·98	999301	·12	754227	37·10	245773	45
16	755747	36·79	999294	·12	756453	36·92	243547	44
17	757955	36·61	999286	·12	758668	36·73	241332	43
18	760151	36·42	999279	·12	760872	36·55	239128	42
19	762337	36·24	999272	·12	763065	36·36	236935	41
20	764511	36·06	999265	·12	765246	36·18	234754	40
21	8·766675	35·88	9·999257	·12	8·767417	36·00	11·232583	39
22	768828	35·70	999250	·13	769578	35·83	230422	38
23	770970	35·53	999242	·13	771727	35·65	228273	37
24	773101	35·35	999235	·13	773866	35·48	226134	36
25	775223	35·18	999227	·13	775995	35·31	224005	35
26	777333	35·01	999220	·13	778114	35·14	221886	34
27	779434	34·84	999212	·13	780222	34·97	219778	33
28	781524	34·67	999205	·13	782320	34·80	217680	32
29	783605	34·51	999197	·13	784408	34·64	215592	31
30	785675	34·31	999189	·13	786486	34·47	213514	30
31	8·787736	34·18	9·999181	·13	8·788554	34·31	11·211446	29
32	789787	34·02	999174	·13	790613	34·15	209387	28
33	791828	33·86	999166	·13	792662	33·99	207338	27
34	793859	33·70	999158	·13	794701	33·83	205299	26
35	795881	33·54	999150	·13	796731	33·68	203269	25
36	797894	33·39	999142	·13	798752	33·52	201248	24
37	799897	33·23	999134	·13	800763	33·37	199237	23
38	801892	33·08	999126	·13	802765	33·22	197235	22
39	803876	32·93	999118	·13	804758	33·07	195242	21
40	805852	32·78	999110	·13	806742	32·92	193258	20
41	8·807819	32·63	9·999102	·13	8·808717	32·78	11·191283	19
42	809777	32·49	999094	·14	810683	32·62	189317	18
43	811726	32·34	999086	·14	812641	32·48	187359	17
44	813667	32·19	999077	·14	814589	32·33	185411	16
45	815599	32·05	999069	14	816529	32·19	183471	15
46	817522	31·91	999061	·14	818461	32·05	181539	14
47	819436	31·77	999053	·14	820384	31·91	179616	13
48	821343	31·63	999044	·14	822298	31·77	177702	12
49	823240	31·49	999036	·14	824205	31·63	175795	11
50	825130	31·35	999027	·14	826103	31·50	173897	10
5	8·827011	31 22	9·999019	·14	8·827992	31·36	11·172008	9
52	828884	31·08	999010	14	829874	31·23	170126	8
53	830749	30·95	999002	·14	831748	31·10	168252	7
54	832607	30·82	998993	·14	833613	30·96	166387	6
55	834456	30·69	998984	·14	835471	30·83	164529	5
56	836297	30·56	998976	·14	837321	30·70	162679	4
57	838130	30·43	998967	·15	837163	30·57	160837	3
58	839956	30·30	998958	·15	840998	30·45	159002	2
59	841774	30·17	998950	·15	842825	30 32	157175	1
60	843585	30·00	998941	·15	844644	30·19	155356	0
	Cosine	D.	Sine		Cotang.	D.	Tang.	M.

(86 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	8·843585	30·05	9·998941	·15	8·844644	30·19	11·155356	60
1	845387	29·92	998932	·15	846455	30·07	153545	59
2	847183	29·80	998923	·15	848260	29·95	151740	58
3	848971	29·67	998914	·15	850057	29·82	149943	57
4	850751	29·55	998905	·15	851846	29·70	148154	56
5	852525	29·43	998896	·15	853628	29·58	146372	55
6	854291	29·31	998887	·15	855403	29·46	144597	54
7	856049	29·19	998878	·15	857171	29·35	142829	53
8	857801	29·07	998869	·15	858932	29·23	141068	52
9	859546	28·96	998860	·15	860686	29·11	139314	51
10	861283	28·84	998851	·15	862433	29·00	137567	50
11	8·863014	28·73	9·998841	·15	8·864173	28·88	11·135827	49
12	864738	28·61	998832	·15	865906	28·77	134094	48
13	866455	28·50	998823	·16	867632	28·66	132368	47
14	868165	28·39	998813	·16	869351	28·54	130649	46
15	869868	28·28	998804	·16	871064	28·43	128936	45
16	871565	28·17	998795	·16	872770	28·32	127230	44
17	873255	28·06	998785	·16	874469	28·21	125531	43
18	874938	27·95	998776	·16	876162	28·11	123838	42
19	876615	27·86	998766	·16	877849	28·00	122151	41
20	878285	27·73	998757	·16	879529	27·89	120471	40
21	8·879949	27·63	9·998747	·16	8·881202	27·79	11·118798	39
22	881607	27·52	998738	·16	882869	27·68	117131	38
23	883258	27·42	998728	·16	884530	27·58	115470	37
24	884903	27·31	998718	·16	886185	27·47	113815	36
25	886542	27·21	998708	·16	887833	27·37	112167	35
26	888174	27·11	998699	·16	889476	27·27	110524	34
27	889801	27·00	998689	·16	891112	27·17	108888	33
28	891421	26·90	998679	·16	892742	27·07	107258	32
29	893035	26·80	998669	·17	894366	26·97	105634	31
30	894643	26·70	998659	·17	895984	26·87	104016	30
31	8·896246	26·60	9·998649	·17	8·897596	26·77	11·102404	29
32	897842	26·51	998639	·17	899203	26·67	100797	28
33	899432	26·41	998629	·17	900803	26·58	099197	27
34	901017	26·31	998619	·17	902398	26·48	097602	26
35	902596	26·22	998609	·17	903987	26·38	096013	25
36	904169	26·12	998599	·17	905570	26·29	094430	24
37	905736	26·03	998589	·17	907147	26·20	092853	23
38	907297	25·93	998578	·17	908719	26·10	091281	22
39	908853	25·84	998568	·17	910285	26·01	089715	21
40	910404	25·75	998558	·17	911846	25·92	088154	20
41	8·911949	25·66	9·998548	·17	8·913401	25·83	11·086599	19
42	913488	25·56	998537	·17	914951	25·74	085049	18
43	915022	25·47	998527	·17	916495	25·65	083505	17
44	916550	25·38	998516	·18	918034	25·56	081966	16
45	918073	25·29	998506	·18	919568	25·47	080432	15
46	919591	25·20	998495	·18	921096	25·38	078904	14
47	921103	25·12	998485	·18	922619	25·30	077381	13
48	922610	25·03	998474	·18	924136	25·21	075864	12
49	924112	24·94	998464	·18	925649	25·12	074351	11
50	925609	24·86	998453	·18	927156	25·03	072844	10
51	8·927100	24·77	9·998442	·18	8·928658	24·95	11·071342	9
52	928587	24·69	998431	·18	930155	24·86	069845	8
53	930068	24·60	998421	·18	931647	24·78	068353	7
54	931544	24·52	998410	·18	933134	24·70	066866	6
55	933015	24·43	998399	·18	934616	24·61	065384	5
56	934481	24·35	998388	·18	936093	24·53	063907	4
57	935942	24·27	998377	·18	937565	24·45	062435	3
58	937398	24·19	998366	·18	939032	24·37	060968	2
59	938850	24·11	998355	·18	940494	24·30	059506	1
60	940296	24·03	998344	·18	941952	24·21	058048	0
	Cosine	D.	Sine		Cotang	D.	Tang.	M.

(85 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	8·940296	24·03	9·998344	·19	8·941952	24·21	11·058048	60
1	941738	23·94	998333	·19	943404	24·13	056596	59
2	943174	23·87	998322	·19	944852	24·05	055148	58
3	944606	23·79	998311	·19	946295	23·97	053705	57
4	946034	23·71	998300	·19	947734	23·90	052266	56
5	947456	23·63	998289	·19	949168	23·82	050832	55
6	948874	23·55	998277	·19	950597	23·74	049403	54
7	950287	23·48	998266	·19	952021	23·66	047979	53
8	951696	23·40	998255	·19	953441	23·60	046559	52
9	953100	23·32	998243	·19	954856	23·51	045144	51
10	954499	23·25	998232	·19	956267	23·44	043733	50
11	8·955894	23·17	9·998220	·19	8·957674	23·37	11·042326	49
12	957284	23·10	998209	·19	959075	23·29	040925	48
13	958670	23·02	998197	·19	960473	23·23	039527	47
14	960052	22·95	998186	·19	961866	23·14	038134	46
15	961429	22·88	998174	·19	963255	23·07	036745	45
16	962801	22·80	998163	·19	964639	23·00	035361	44
17	964170	22·73	998151	·19	966019	22·93	033981	43
18	965534	22·66	998139	·20	967394	22·86	032606	42
19	966893	22·59	998128	·20	968766	22·79	031234	41
20	968249	22·52	998116	·20	970133	22·71	029867	40
21	8·969600	22·44	9·998104	·20	8·971496	22·65	11·028504	39
22	970947	22·38	998092	·20	972855	22·57	027145	38
23	972289	22·31	998080	·20	974209	22·51	025791	37
24	973628	22·24	998068	·20	975560	22·44	024440	36
25	974962	22·17	998056	·20	976906	22·37	023094	35
26	976293	22·10	998044	·20	978248	22·30	021752	34
27	977619	22·03	998032	·20	979586	22·23	020414	33
28	978941	21·97	998020	·20	980921	22·17	019079	32
29	980259	21·90	998008	·20	982251	22·10	017749	31
30	981573	21·83	997996	·20	983577	22·04	016423	30
31	8·982883	21·77	9·997985	·20	8·984899	21·97	11·015101	29
32	984189	21·70	997972	·20	986217	21·91	013783	28
33	985491	21·63	997959	·20	987532	21·84	012468	27
34	986789	21·57	997947	·20	988842	21·78	011158	26
35	988083	21·50	997935	·21	990149	21·71	009851	25
36	989374	21·44	997922	·21	991451	21·65	008549	24
37	990660	21·38	997910	·21	992750	21·58	007250	23
38	991943	21·31	997897	·21	994045	21·52	005955	22
39	993222	21·25	997885	·21	995337	21·46	004663	21
40	994497	21·19	997872	·21	996624	21·40	003376	20
41	8·995768	21·12	9·997860	·21	8·997908	21·34	11·002092	19
42	997036	21·06	997847	·21	999188	21·27	000812	18
43	998299	21·00	997835	·21	9·000465	21·21	10·999535	17
44	999560	20·94	997822	·21	001735	21·15	998262	16
45	9·000816	20·87	997809	·21	003007	21·09	996993	15
46	002069	20·82	997797	·21	004272	21·03	995728	14
47	003318	20·76	997784	·21	005534	20·97	994466	13
48	004563	20·70	997771	·21	006792	20·91	993208	12
49	005805	20·64	997758	·21	008047	20·85	991953	11
50	007044	20·58	997745	·21	009298	20·80	990702	10
51	9·008278	20·52	9·997732	·21	9·010546	20·74	10·989454	9
52	009510	20·46	997719	·21	011790	20·68	988210	8
53	010737	20·40	997706	·21	013031	20·62	986969	7
54	011962	20·34	997693	·22	014268	20·56	985732	5
55	013182	20·29	997680	·22	015502	20·51	984498	5
56	014400	20·23	997667	·22	016732	20·45	983268	4
57	015613	20·17	997654	·22	017959	20·40	982041	3
58	016824	20·12	997641	·22	019183	20·33	980817	2
59	018031	20·06	997628	·22	020403	20·28	979597	
60	019235	20·00	997614	·22	021620	20·23	978380	
	Cosine	D.	Sine		Cotang.	D.	Tang.	

M	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·019235	20·00	9·997614	·22	9·021620	20·23	10·978380	60
1	020435	19·95	997601	·22	022834	20·17	977166	59
2	021632	19·89	997588	·22	024044	20·11	975956	58
3	022825	19·84	997574	·22	025251	20·06	974749	57
4	024016	19·78	997561	·22	026455	20·00	973545	56
5	025203	19·73	997547	·22	027655	19·95	972345	55
6	026386	19·67	997534	·23	028852	19·90	971148	54
7	027567	19·62	997520	·23	030046	19·85	969954	53
8	028744	19·57	997507	·23	031237	19·79	968763	52
9	029918	19·51	997493	·23	032425	19·74	967575	51
10	031089	19·47	997480	·23	033609	19·69	966391	50
11	9·032257	19·41	9·997466	·23	9·034791	19·64	10·965209	49
12	033421	19·36	997452	·23	035969	19·58	964031	48
13	034582	19·30	997439	·23	037144	19·53	962856	47
14	035741	19·25	997425	·23	038316	19·48	961684	46
15	036896	19·20	997411	·23	039485	19·43	960515	45
16	038048	19·15	997397	·23	040651	19·38	959349	44
17	039197	19·10	997383	·23	041813	19·33	958187	43
18	040342	19·05	997369	·23	042973	19·28	957027	42
19	041485	18·99	997355	·23	044130	19·23	955870	41
20	042625	18·94	997341	·23	045284	19·18	954716	40
21	9·043762	18·89	9·997327	·24	9·046434	19·13	10·953566	39
22	044895	18·84	997313	·24	047582	19·08	952418	38
23	046026	18·79	997299	·24	048727	19·03	951273	37
24	047154	18·75	997285	·24	049869	18·98	950131	36
25	048279	18·70	997271	·24	051008	18·93	948992	35
26	049400	18·65	997257	·24	052144	18·89	947856	34
27	050519	18·60	997242	·24	053277	18·84	946723	33
28	051635	18·55	997228	·24	054407	18·79	945593	32
29	052749	18·50	997214	·24	055535	18·74	944465	31
30	053859	18·45	997199	·24	056659	18·70	943341	30
31	9·054966	18·41	9·997185	·24	9·057781	18·65	10·942219	29
32	056071	18·36	997170	·24	058900	18·60	941100	28
33	057172	18·31	997156	·24	060016	18·55	939984	27
34	058271	18·27	997141	·24	061130	18·51	938870	26
35	059367	18·22	997127	·24	062240	18·46	937760	25
36	060460	18·17	997112	·24	063348	18·42	936652	24
37	061551	18·13	997098	·24	064453	18·37	935547	23
38	062639	18·08	997083	·25	065556	18·32	934444	22
39	063724	18·04	997068	·25	066655	18·28	933345	21
40	064806	17·99	997053	·25	067752	18·24	932248	20
41	9·065885	17·94	9·997039	·25	9·068846	18·19	10·931154	19
42	066962	17·90	997024	·25	069938	18·15	930062	18
43	068036	17·86	997009	·25	071027	18·10	928973	17
44	069107	17·81	996994	·25	072113	18·06	927887	16
45	070176	17·77	996979	·25	073197	18·02	926803	15
46	071242	17·72	996964	·25	074278	17·97	925722	14
47	072306	17·68	996949	·25	075356	17·93	924644	13
48	073366	17·63	996934	·25	076432	17·89	923568	12
49	074424	17·59	996919	·25	077505	17·84	922495	11
50	075480	17·55	996904	·25	078576	17·80	921424	10
51	9·076533	17·50	9·996889	·25	9·079644	17·76	10·920356	9
52	077583	17·46	996874	·25	080710	17·72	919290	8
53	078631	17·42	996858	·25	081773	17·67	918227	7
54	079676	17·38	996843	·25	082833	17·63	917167	6
55	080719	17·33	996828	·25	083891	17·59	916109	5
56	081759	17·29	996812	·26	084947	17·55	915053	4
57	082797	17·25	996797	·26	086000	17·51	914000	3
58	083832	17·21	996782	·26	087050	17·47	912950	2
59	084864	17·17	996766	·26	088098	17·43	911902	1
60	085894	17·13	996751	·26	089144	17·38	910856	0
	Cosine	D.	Sine		Cotang.	D.	Tang.	M.

(83 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·085894	17·13	9·996751	·26	9·089.44	17·38	10·910856	60
1	086922	17·09	996735	·26	090181	17·34	909813	59
2	087947	17·04	996720	·26	091228	17·30	908772	58
3	088970	17·00	996704	·26	092266	17·27	907734	57
4	089990	16·96	996688	·26	093302	17·22	906698	56
5	091008	16·92	996673	·26	094336	17·19	905664	55
6	092024	16·88	996657	·26	095367	17·15	904633	54
7	093037	16·84	996641	·26	096395	17·11	903605	53
8	094047	16·80	996625	·26	097422	17·07	902578	52
9	095056	16·76	996610	·26	098446	17·03	901554	51
10	096062	16·73	996594	·26	099468	16·99	900532	50
11	9·097065	16·68	9·996578	·27	9·100487	16·95	10·899513	49
12	098066	16·65	996562	·27	101504	16·91	898496	48
13	099065	16·61	996546	·27	102519	16·87	897481	47
14	100062	16·57	996530	·27	103532	16·84	896468	46
15	101056	16·53	996514	·27	104542	16·80	895458	45
16	102048	16·49	996498	·27	105550	16·76	894450	44
17	103037	16·45	996482	·27	106556	16·72	893444	43
18	104025	16·41	996465	·27	107559	16·69	892441	42
19	105010	16·38	996449	·27	108560	16·65	891440	41
20	105992	16·34	996433	·27	109559	16·61	890441	40
21	9·106973	16·30	9·996417	·27	9·110556	16·58	10·889444	39
22	107951	16·27	996400	·27	111551	16·54	888449	38
23	108927	16·23	996384	·27	112543	16·50	887457	37
24	109901	16·19	996368	·27	113533	16·46	886467	36
25	110873	16·16	996351	·27	114521	16·43	885479	35
26	111842	16·12	996335	·27	115507	16·39	884493	34
27	112809	16·08	996318	·27	116491	16·36	883509	33
28	113774	16·05	996302	·28	117472	16·32	882528	32
29	114737	16·01	996285	·28	118452	16·29	881548	31
30	115698	15·97	996269	·28	119429	16·25	880571	30
31	9·116656	15·94	9·996252	·28	9·120404	16·22	10·879596	29
32	117613	15·90	996235	·28	121377	16·18	878623	28
33	118567	15·87	996219	·28	122348	16·15	877652	27
34	119519	15·83	996202	·28	123317	16·11	876683	26
35	120469	15·80	996185	·28	124284	16·07	875716	25
36	121417	15·76	996168	·28	125249	16·04	874751	24
37	122362	15·73	996151	·28	126211	16·01	873789	23
38	123306	15·69	996134	·28	127172	15·97	872828	22
39	124248	15·66	996117	·28	128130	15·94	871870	21
40	125187	15·62	996100	·28	129087	15·91	870913	20
41	9·126125	15·59	9·996083	·29	9·130041	15·87	10·869959	19
42	127060	15·56	996066	·29	130994	15·84	869006	18
43	127993	15·52	996049	·29	131944	15·81	868056	17
44	128925	15·49	996032	·29	132893	15·77	867107	16
45	129854	15·45	996015	·29	133839	15·74	866161	15
46	130781	15·42	995998	·29	134784	15·71	865216	14
47	131706	15·39	995980	·29	135726	15·67	864274	13
48	132630	15·35	995963	·29	136667	15·64	863333	12
49	133551	15·32	995946	·29	137605	15·61	862395	11
50	134470	15·29	995928	·29	138542	15·58	861458	10
51	9·135387	15·25	9·995911	·29	9·139476	15·55	10·860524	9
52	136303	15·22	995894	·29	140409	15·51	859591	8
53	137216	15·19	995876	·29	141340	15·48	858660	7
54	138128	15·16	995859	·29	142269	15·45	857731	6
55	139037	15·12	995841	·29	143196	15·42	856804	5
56	139944	15·09	995823	·29	144121	15·39	855879	4
57	140850	15·06	995806	·29	145044	15·35	854956	3
58	141754	15·03	995788	·29	145966	15·32	854034	2
59	142655	15·00	995771	·29	146885	15·29	853115	1
60	143555	14·96	995753	·29	147803	15·26	852197	0
	Cosine	D.	Sine		Cotang.	D.	Tang.	

(82 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·143555	14·96	9·995753	·30	9·147803	15·26	10·852197	60
1	144453	14·93	995735	·30	148718	15·23	851282	59
2	145349	14·90	995717	·30	149632	15·20	850368	58
3	146243	14·87	995699	·30	150544	15·17	849456	57
4	147136	14·84	995681	·30	151454	15·14	848546	56
5	148026	14·81	995664	·30	152363	15·11	847637	55
6	148915	14·78	995646	·30	153269	15·08	846731	54
7	149802	14·75	995628	·30	154174	15·05	845826	53
8	150686	14·72	995610	·30	155077	15·02	844923	52
9	151569	14·69	995591	·30	155978	14·99	844022	51
10	152451	14·66	995573	·30	156877	14·96	843123	50
11	9·1 3330	14·63	9·995555	·30	9·157775	14·93	10·842225	49
12	154208	14·60	995537	·30	158671	14·90	841329	48
13	155083	14·57	995519	·30	159565	14·87	840435	47
14	155957	14·54	995501	·31	160457	14·84	839543	46
15	156830	14·51	995482	·31	161347	14·81	838653	45
16	157700	14·48	995464	·31	162236	14·79	837764	44
17	158569	14·45	995446	·31	163123	14·76	836877	43
18	159435	14·42	995427	·31	164008	14·73	835992	42
19	160301	14·39	995409	·31	164892	14·70	835108	41
20	161164	14·36	995390	·31	165774	14·67	834226	40
21	9·162025	14·33	9·995372	·31	9·166654	14·64	10·833346	39
22	162885	14·30	995353	·31	167532	14·61	832468	38
23	163743	14·27	995334	·31	168409	14·58	831591	37
24	164600	14·24	995316	·31	169284	14·55	830716	36
25	165454	14·22	995297	·31	170157	14·53	829843	35
26	166307	14·19	995278	·31	171029	14·50	828971	34
27	167159	14·16	995260	·31	171899	14·47	828101	33
28	168008	14·13	995241	·32	172767	14·44	827233	32
29	168856	14·10	995222	·32	173634	14·42	826366	31
30	169702	14·07	995203	·32	174499	14·39	825501	30
31	9·170547	14·05	9·995184	·32	9·175362	14·36	10·824638	29
32	171389	14·02	995165	·32	176224	14·33	823776	28
33	172230	13·99	995146	·32	177084	14·31	822916	27
34	173070	13·96	995127	·32	177942	14·28	822058	26
35	173908	13·94	995108	·32	178799	14·25	821201	25
36	174744	13·91	995089	·32	179655	14·23	820345	24
37	175578	13·88	995070	·32	180508	14·20	819492	23
38	176411	13·86	995051	·32	181360	14·17	818640	22
39	177242	13·83	995032	·32	182211	14·15	817789	21
40	178072	13·80	995013	·32	183059	14·12	816941	20
41	9·178900	13·77	9·994993	·32	9·183907	14·09	10·816093	19
42	179726	13·74	994974	·32	184752	14·07	815248	18
43	180551	13·72	994955	·32	185597	14·04	814403	17
44	181374	13·69	994935	·32	186439	14·02	813561	16
45	182196	13·66	994916	·33	187280	13·99	812720	15
46	183016	13·64	994896	·33	188120	13·96	811880	14
47	183834	13·61	994877	·33	188958	13·93	811042	13
48	184651	13·59	994857	·33	189794	13·91	810206	12
49	185466	13·56	994838	·33	190629	13·89	809371	11
50	186280	13·53	994818	·33	191462	13·86	808538	10
51	9·187092	13·51	9·994798	·33	9·192294	13·84	10·807706	9
52	187903	13·48	994779	·33	193124	13·81	806876	8
53	188712	13·46	994759	·33	193953	13·79	806047	7
54	180519	13·43	994739	·33	194780	13·76	805220	5
55	190325	13·41	994719	·33	195606	13·74	804394	5
56	191130	13·38	994700	·33	196430	13·71	803570	4
57	191933	13·36	994680	·33	197253	13·69	802747	3
58	192734	13·33	994660	·33	198074	13·66	801926	2
59	193534	13·30	994640	·33	198894	13·64	801106	1
60	194332	13·28	994620	·33	199713	13·61	800287	0
	Cosine	D.	Sine		Cotang.	D.	Tang.	M.

M.	Sine	D.	Cosine	D.	Tang	D.	Cotang.	
0	9·194332	13·28	9·994620	·33	9·199713	13·61	10·800287	60
1	195129	13·26	994600	·33	200529	13·59	799471	59
2	195925	13·23	994580	·33	201345	13·56	798655	58
3	196719	13·21	994560	34	202159	13·54	797841	57
4	197511	13·18	994540	·34	202971	13·52	797029	56
5	198302	13·16	994519	·34	203782	13·49	796218	55
6	199091	13·13	994499	·34	204592	13·47	795408	54
7	199879	13·11	994479	·34	205400	13·45	794600	53
8	200666	13·08	994459	·34	206207	13·42	793793	52
9	201451	13·06	994438	·34	207013	13·40	792987	51
10	202234	13·04	994418	·34	207817	13·38	792183	50
11	9·203017	13·01	9·994397	·34	9·208619	13·35	10·791381	49
12	203797	12·99	994377	·34	209420	13·33	790580	48
13	204577	12·96	994357	·34	210220	13·31	789780	47
14	205354	12·94	994336	·34	211018	13·28	788982	46
15	206131	12·92	994316	·34	211815	13·26	788185	45
16	206906	12·89	994295	·34	212611	13·24	787389	44
17	207679	12·87	994274	·35	213405	13·21	786595	43
18	208452	12·85	994254	·35	214198	13·19	785802	42
19	209222	12·82	994233	·35	214989	13·17	785011	41
20	209992	12·80	994212	·35	215780	13·15	784220	40
21	9·210760	12·78	9·994191	·35	9·216568	13·12	10·783432	39
22	211526	12·75	994171	·35	217356	13·10	782644	38
23	212291	12·73	994150	·35	218142	13·08	781858	37
24	213055	12·71	994129	·35	218926	13·05	781074	36
25	213818	12·68	994108	·35	219710	13·03	780290	35
26	214579	12·66	994087	·35	220492	13·01	779508	34
27	215338	12·64	994066	·35	221272	12·99	778728	33
28	216097	12·61	994045	·35	222052	12·97	777948	32
29	216854	12,59	994024	·35	222830	12·94	777170	31
30	217609	12·57	994003	·35	223606	12·92	776394	30
31	9·218363	12·55	9·993981	·35	9·224382	12·90	10·775618	29
32	219116	12·53	993960	·35	225156	12·88	774844	28
33	219868	12·50	993939	·35	225929	12·86	774071	27
34	220618	12·48	993918	·35	226700	12·84	773300	26
35	221367	12·46	993896	·36	227471	12·81	772529	25
36	222115	12·44	993875	·36	228239	12·79	771761	24
37	222861	12·42	993854	·36	229007	12·77	770993	23
38	223606	12·39	993832	·36	229773	12·75	770227	22
39	224349	12·37	993811	·36	230539	12·73	769461	21
40	225092	12·35	993789	·36	231302	12·71	768698	20
41	9·225833	12·33	9·993768	·36	9·232065	12·69	10·767935	19
42	226573	12·31	993746	·36	232826	12·67	767174	18
43	227311	12·28	993725	·36	233586	12·65	766414	17
44	228048	12·26	993703	·36	234345	12·62	765655	16
45	228784	12·24	993681	·36	235103	12·60	764897	15
46	229518	12·22	993660	·36	235859	12·58	764141	14
47	230252	12·20	993638	·36	236614	12·56	763386	13
48	230984	12·18	993616	·36	237368	12·54	762632	12
49	231714	12·16	993594	·37	238120	12·52	761880	11
50	232444	12·14	993572	·37	238872	12·50	761128	10
51	9·233172	12·12	9·993550	·37	9·239622	12·48	10·760378	9
52	233899	12·09	993528	·37	240371	12·46	759629	8
53	234625	12·07	993506	·37	241118	12·44	758882	7
54	235349	12·05	993484	·37	241865	12·42	758135	6
55	236073	12·03	993462	·37	242610	12·40	757390	5
56	236795	12·01	993440	·37	243354	12·38	756646	4
57	237515	11·99	993418	·37	244097	12·36	755903	3
58	238235	11·97	993396	·37	244839	12·34	755161	2
59	238953	11·95	993374	·37	245579	12·33	754421	1
60	239670	11·93	993351	·37	246319	12·30	753681	0
	Cosine	D.	Sine		Cotang.	D.	Tang.	M.

(80 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·239670	11·93	9·993351	·37	9·246319	12·30	10·753681	60
1	240386	11·91	993329	·37	247057	12·28	752943	59
2	241101	11·89	993307	·37	247794	12·26	752206	58
3	241814	11·87	993285	·37	248530	12·24	751470	57
4	242526	11·85	993262	·37	249264	12·22	750736	56
5	243237	11·83	993240	·37	249998	12·20	750002	55
6	243947	11·81	993217	·38	250730	12·18	749270	54
7	244656	11·79	993195	·38	251461	12·17	748539	53
8	245363	11·77	993172	·38	252191	12·15	747809	52
9	246069	11·75	993149	·38	252920	12·13	747080	51
10	246775	11·73	993127	·38	253648	12·11	746352	50
11	9·247478	11·71	9·993104	·38	9·254374	12·09	10·745626	49
12	248181	11·69	993081	·38	255100	12·07	744900	48
13	248883	11·67	993059	·38	255824	12·05	744176	47
14	249583	11·65	993036	·38	256547	12·03	743453	46
15	250282	11·63	993013	·38	257269	12·01	742731	45
16	250980	11·61	992990	·38	257990	12·00	742010	44
17	251677	11·59	992967	·38	258710	11·98	741290	43
18	252373	11·58	992944	·38	259429	11·96	740571	42
19	253067	11·56	992921	·38	260146	11·94	739854	41
20	253761	11·54	992898	·38	260863	11·92	739137	40
21	9·254453	11·52	9·992875	·38	9·261578	11·90	10·738422	39
22	255144	11·50	992852	·38	262292	11·89	737708	38
23	255834	11·48	992829	·39	263005	11·87	736995	37
24	256523	11·46	992806	·39	263717	11·85	736283	36
25	257211	11·44	992783	·39	264428	11·83	735572	35
26	257898	11·42	992759	·39	265138	11·81	734862	34
27	258583	11·41	992736	·39	265847	11·79	734153	33
28	259268	11·39	992713	·39	266555	11·78	733445	32
29	259951	11·37	992690	·39	267261	11·76	732739	31
30	260633	11·35	992666	·39	267967	11·74	732033	30
31	9·261314	11·33	9·992643	·39	9·268671	11·72	10·731329	29
32	261994	11·31	992619	·39	269375	11·70	730625	28
33	262673	11·30	992596	·39	270077	11·69	729923	27
34	263351	11·28	992572	·39	270779	11·67	729221	26
35	264027	11·26	992549	·39	271479	11·65	728521	25
36	264703	11·24	992525	·39	272178	11·64	727822	24
37	265377	11·22	992501	·39	272876	11·62	727124	23
38	266051	11·20	992478	·40	273573	11·60	726427	22
39	266723	11·19	992454	·40	274269	11·58	725731	21
40	267395	11·17	992430	·40	274964	11·57	725036	20
41	9·268065	11·15	9·992406	·40	9·275658	11·55	10·724342	19
42	268734	11·13	992382	·40	276351	11·53	723649	18
43	269402	11·11	992359	·40	277043	11·51	722957	17
44	270069	11·10	992335	·40	277734	11·50	722266	16
45	270735	11·08	992311	·40	278424	11·48	721576	15
46	271400	11·06	992287	·40	279113	11·47	720887	14
47	272064	11·05	992263	·40	279801	11·45	720199	13
48	272726	11·03	992239	·40	280488	11·43	719512	12
49	273388	11·01	992214	·40	281174	11·41	718826	11
50	274049	10·99	992190	·40	281858	11·40	718142	10
51	9·274708	10·98	9·992166	·40	9·282542	11·38	10·717458	9
52	275367	10·96	992142	·40	283225	11·36	716775	8
53	276024	10·94	992117	·41	283907	11·35	716093	7
54	276681	10·92	992093	·41	284588	11·33	715412	6
55	277337	10·91	992069	·41	285268	11·31	714732	5
56	277991	10·89	992044	·41	285947	11·30	714053	4
57	278644	10·87	992020	·41	286624	11·28	713376	3
58	279297	10·86	991996	·41	287301	11·26	712699	2
59	279948	10·84	991971	·41	287977	11·25	712023	1
60	280599	10·82	991947	·41	288652	11·23	711348	0
	Cosine	D.	Sine		Cotang.	D.	Tang.	M.

(79 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·280599	10·82	9·991947	·41	9·288652	11·23	10·711348	60
1	281248	10·81	991922	·41	289326	11·22	710674	59
2	281897	10·79	991897	·41	289999	11·20	710001	58
3	282544	10·77	991873	·41	290671	11·18	709329	57
4	283190	10·76	991848	·41	291342	11·17	708658	56
5	283836	10·74	991823	·41	292013	11·15	707987	55
6	284480	10·72	991799	·41	292682	11·14	707318	54
7	285124	10·71	991774	·42	293350	11·12	706650	53
8	285766	10·69	991749	·42	294017	11·11	705983	52
9	286408	10·67	991724	·42	294684	11·09	705316	51
10	287048	10·66	991699	·42	295349	11·07	704651	50
11	9·287687	10·64	9·991674	·42	9·296013	11·06	10·703987	49
12	288326	10·63	991649	·42	296677	11·04	703323	48
13	288964	10·61	991624	·42	297339	11·03	702661	47
14	289600	10·59	991599	·42	298001	11·01	701999	46
15	290236	10·58	991574	·42	298662	11·00	701338	45
16	290870	10·56	991549	·42	299322	10·98	700678	44
17	291504	10·54	991524	·42	299980	10·96	700020	43
18	292137	10·53	991498	·42	300638	10·95	699362	42
19	292768	10·51	991473	·42	301295	10·93	698705	41
20	293399	10·50	991448	·42	301951	10·92	698049	40
21	9·294029	10·48	9·991422	·42	9·302607	10·90	10·697393	39
22	294658	10·46	991397	·42	303261	10·89	696739	38
23	295286	10·45	991372	·43	303914	10·87	696086	37
24	295913	10·43	991346	·43	304567	10·86	695433	36
25	296539	10·42	991321	·43	305218	10·84	694782	35
26	297164	10·40	991295	·43	305869	10·83	694131	34
27	297788	10·39	991270	·43	306519	10·81	693481	33
28	298412	10·37	991244	·43	307168	10·80	692832	32
29	299034	10·36	991218	·43	307815	10·78	692185	31
30	299655	10·34	991193	·43	308463	10·77	691537	30
31	9·300276	10·32	9·991167	·43	9·309109	10·75	10·690891	29
32	300895	10·31	991141	·43	309754	10·74	690246	28
33	301514	10·29	991115	·43	310398	10·73	689602	27
34	302132	10·28	991090	·43	311042	10·71	688958	26
35	302748	10·26	991064	·43	311685	10·70	688315	25
36	303364	10·25	991038	·43	312327	10·68	687673	24
37	303979	10·23	991012	·43	312967	10·67	687033	23
38	304593	10·22	990986	·43	313608	10·65	686392	22
39	305207	10·20	990960	·43	314247	10·64	685753	21
40	305819	10·19	990934	·44	314885	10·62	685115	20
41	9·306430	10·17	9·990908	·44	9·315523	10·61	10·684477	19
42	307041	10·16	990882	·44	316159	10·60	683841	18
43	307650	10·14	990855	·44	316795	10·58	683205	17
44	308259	10·13	990829	·44	317430	10·57	682570	16
45	308867	10·11	990803	·44	318064	10·55	681936	15
46	309474	10·10	990777	·44	318697	10·54	681303	14
47	310080	10·08	990750	·44	319329	10·53	680671	13
48	310685	10·07	990724	·44	319961	10·51	680039	12
49	311289	10·05	990697	·44	320592	10·50	679408	11
50	311893	10·04	990671	·44	321222	10·48	678778	10
51	9·312495	10·03	9·990644	·44	9·321851	10·47	10·678149	9
52	313097	10·01	990618	·44	322479	10·45	677521	8
53	313698	10·00	990591	·44	323106	10·44	676894	7
54	314297	9·98	990565	·44	323733	10·43	676267	6
55	314897	9·97	990538	·44	324358	10·41	675642	5
56	315495	9·96	990511	·45	324983	10·40	675017	4
57	316092	9·94	990485	·45	325607	10·39	674393	3
58	316689	9·93	990458	·45	326231	10·37	673769	2
59	317284	9·91	990431	·45	326853	10·36	673147	1
60	317879	9·90	990404	·45	327475	10·35	672525	0
	Cosine	D.	Sine		Cotang.	D.		

(78 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·317879	9·90	9·990404	·45	9·327474	10·35	10·672526	60
1	318473	9·88	990378	·45	328095	10·33	671905	59
2	319066	9·87	990351	·45	328715	10·32	671285	58
3	319658	9·86	990324	·45	329334	10·30	670666	57
4	320249	9·84	990297	·45	329953	10·29	670047	56
5	320840	9·83	990270	·45	330570	10·28	669430	55
6	321430	9·82	990243	·45	331187	10·26	668813	54
7	322019	9·80	990215	·45	331803	10·25	668197	53
8	322607	9·79	990188	·45	332418	10·24	667582	52
9	323194	9·77	990161	·45	333033	10·23	666967	51
10	323780	9·76	990134	·45	333646	10·21	666354	50
11	9·324366	9·75	9·990107	·46	9·334259	10·20	10·665741	49
12	324950	9·73	990079	·46	334871	10·19	665129	48
13	325534	9·72	990052	·46	335482	10·17	664518	47
14	326117	9·70	990025	·46	336093	10·16	663907	46
15	326700	9·69	989997	·46	336702	10·15	663298	45
16	327281	9·68	989970	·46	337311	10·13	662689	44
17	327862	9·66	989942	·46	337919	10·12	662081	43
18	328442	9·65	989915	·46	338527	10·11	661473	42
19	329021	9·64	989887	·46	339133	10·10	660867	41
20	329599	9·62	989860	·46	339739	10·08	660261	40
21	9·330176	9·61	9·989832	·46	9·340344	10·07	10·659656	39
22	330753	9·60	989804	·46	340948	10·06	659052	38
23	331329	9·58	989777	·46	341552	10·04	658448	37
24	331903	9·57	989749	·47	342155	10·03	657845	36
25	332478	9·56	989721	·47	342757	10·02	657243	35
26	333051	9·54	989693	·47	343358	10·00	656642	34
27	333624	9·53	989665	·47	343958	9·99	656042	33
28	334195	9·52	989637	·47	344558	9·98	655442	32
29	334766	9·50	989609	·47	345157	9·97	654843	31
30	335337	9·49	989582	·47	345755	9·96	654245	30
31	9·335906	9·48	9·989553	·47	9·346353	9·94	10·653647	29
32	336475	9·46	989525	·47	346949	9·93	653051	28
33	337043	9·45	989497	·47	347545	9·92	652455	27
34	337610	9·44	989469	·47	348141	9·91	651859	26
35	338176	9·43	989441	·47	348735	9·90	651265	25
36	338742	9·41	989413	·47	349329	9·88	650671	24
37	339306	9·40	989384	·47	349922	9·87	650078	23
38	339871	9·39	989356	·47	350514	9·86	649486	22
39	340434	9·37	989328	·47	351106	9·85	648894	21
40	340996	9·36	989300	·47	351697	9·83	648303	20
41	9·341558	9·35	9·989271	·47	9·352287	9·82	10·647713	19
42	342119	9·34	989243	·47	352876	9·81	647124	18
43	342679	9·32	989214	·47	353465	9·80	646535	17
44	343239	9·31	989186	·47	354053	9·79	645947	6
45	343797	9·30	989157	·47	354640	9·77	645360	15
46	344355	9·29	989128	·48	355227	9·76	644773	14
47	344912	9·27	989100	·48	355813	9·75	644187	13
48	345469	9·26	989071	·48	356398	9·74	643602	12
49	346024	9·25	989042	·48	356982	9·73	643018	11
50	346579	9·24	989014	·48	357566	9·71	642434	10
51	9·347134	9·22	9·988985	·48	9·358149	9·70	10·641851	9
52	347687	9·21	988956	·48	358731	9·69	641269	8
53	348240	9·20	988927	·48	359313	9·68	640687	7
54	348792	9·19	988898	·48	359893	9·67	640107	6
55	349343	9·17	988869	·48	360474	9·66	639526	5
56	349893	9·16	988840	·48	361053	9·65	638947	4
57	350443	9·15	988811	·49	361632	9·63	638368	3
58	350992	9·14	988782	·49	362210	9·62	637790	2
59	351540	9·13	988753	·49	362787	9·61	637213	1
60	352088	9·11	988724	·49	363364	9·60	636636	0
	Cosine	D.	Sine		Cotang.	D.	Tang.	M.

(77 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·352088	9·11	9·988724	·49	9·363364	9·60	10·636636	60
1	352635	9·10	988695	·49	363940	9·59	636060	59
2	353181	9·09	988666	·49	364515	9·58	635485	58
3	353726	9·08	988636	·49	365090	9·57	634910	57
4	354271	9·07	988607	·49	365664	9·55	634336	56
5	354815	9·05	988578	·49	366237	9·54	633763	55
6	355358	9·04	988548	·49	366810	9·53	633190	54
7	355901	9·03	988519	·49	367382	9·52	632618	53
8	356443	9·02	988489	·49	367953	9·51	632047	52
9	356984	9·01	988460	·49	368524	9·50	631476	51
10	357524	8·99	988430	·49	369094	9·49	630906	50
11	9·358064	8·98	9·988401	·49	9·369663	9·48	10·630337	49
12	358603	8·97	988371	·49	370232	9·46	629768	48
13	359141	8·96	988342	·49	370799	9·45	629201	47
14	359678	8·95	988312	·50	371367	9·44	628633	46
15	360215	8·93	988282	·50	371933	9·43	628067	45
16	360752	8·92	988252	·50	372499	9·42	627501	44
17	361287	8·91	988223	·50	373064	9·41	626936	43
18	361822	8·90	988193	·50	373629	9·40	626371	42
19	362356	8·89	988163	·50	374193	9·39	625807	41
20	362889	8·88	988133	·50	374756	9·38	625244	40
21	9·363422	8·87	9·988103	·50	9·375319	9·37	10·624681	39
22	363954	8·85	988073	·50	375881	9·35	624119	38
23	364485	8·84	988043	·50	376442	9·34	623558	37
24	365016	8·83	988013	·50	377003	9·33	622997	36
25	355546	8·82	987983	·50	377563	9·32	622437	35
26	366075	8·81	987953	·50	378122	9·31	621878	34
27	366604	8·80	987922	·50	378681	9·30	621319	33
28	367131	8·79	987892	·50	379239	9·29	620761	32
29	367659	8·77	987862	·50	379797	9·28	620203	31
30	368185	8·76	987832	·51	380354	9·27	619646	30
31	9·368711	8·75	9·987801	·51	9·380910	9·26	10·619090	29
32	369236	8·74	987771	·51	381466	9·25	618534	28
33	369761	8·73	987740	·51	382020	9·24	617980	27
34	370285	8·72	987710	·51	382575	9·23	617425	26
35	370808	8·71	987679	·51	383129	9·42	616871	25
36	371330	8·70	987649	·51	383682	9·21	616318	24
37	371852	8·69	987618	·51	384234	9·20	615766	23
38	372373	8·67	987588	·51	384786	9·19	615214	22
39	372894	8·66	987557	·51	385337	9·18	614663	21
40	373414	8·65	987526	·51	385888	9·17	614112	20
41	9·373933	8·64	9·987496	·51	9·386438	9·15	10·613562	19
42	374452	8·63	987465	·51	386987	9·14	613013	18
43	374970	8·62	987434	·51	387536	9·13	612464	17
44	375487	8·61	987403	·52	388084	9·12	611916	16
45	376003	8·60	987372	·52	388631	9·11	611369	15
46	376519	8·59	987341	·52	389178	9·10	610822	14
47	377035	8·58	987310	·52	389724	9·09	610276	13
48	377549	8·57	987279	·52	390270	9·08	609730	12
49	378063	8·56	987248	·52	390815	9·07	609185	11
50	378577	8·54	987217	·52	391360	9·06	608640	10
51	9·370089	8·53	9·987186	·52	9·391903	9·05	10·608097	9
52	379601	8·52	987155	·52	392447	9·04	607553	8
53	380113	8·51	987124	·52	392989	9·03	607011	7
54	380624	8·50	987092	·52	393531	9·02	606469	6
55	381134	8·49	987061	·52	394073	9·01	605927	5
56	381643	8·48	987030	·52	394614	9·00	605386	4
57	382152	8·47	986998	·52	395154	8·99	604846	3
58	382661	8·46	986967	·52	395694	8·98	604306	
59	383168	8·45	986936	·52	396233	8·97	603767	
60	383675	8·44	986904	·52	396771	8·96	603229	
	Cosine	D.	Sine		Cotang.	D.	Tang.	

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·489982	6·48	9·978206	·68	9·511776	7·16	10·488224	60
1	490371	6·48	978165	·68	512206	7·16	487794	59
2	490759	6·47	978124	·68	512635	7·15	487365	58
3	491147	6·46	978083	·69	513064	7·14	486936	57
4	491535	6·46	978042	·69	513493	7·14	486507	56
5	491922	6·45	978001	·69	513921	7·13	486079	55
6	492308	6·44	977959	·69	514349	7·13	485651	54
7	492695	6·44	977918	·69	514777	7·12	485223	53
8	493081	6·43	977877	·69	515204	7·12	484796	52
9	493466	6·42	977835	·69	515631	7·11	484369	51
10	493851	6·42	977794	·69	516057	7·10	483943	50
11	9·494236	6·41	9·977752	·69	9·516484	7·10	10·483516	49
12	494621	6·41	977711	·69	516910	7·09	483090	48
13	495005	6·40	977669	·69	517335	7·09	482665	47
14	495388	6·39	977628	·69	517761	7·08	482239	46
15	495772	6·39	977586	·69	518185	7·08	481815	45
16	496154	6·38	977544	·70	518610	7·07	481390	44
17	496537	6·37	977503	·70	519034	7·06	480966	43
18	496919	6·37	977461	·70	519458	7·06	480542	42
19	497301	6·36	977419	·70	519882	7·05	480118	41
20	497682	6·36	977377	·70	520305	7·05	479695	40
21	9·498064	6·35	9·977335	·70	9·520728	7·04	10·479272	39
22	498444	6·34	977293	·70	521151	7·03	478849	38
23	498825	6·34	977251	·70	521573	7·03	478427	37
24	499204	6·33	977209	·70	521995	7·03	478005	36
25	499584	6·32	977167	·70	522417	7·02	477583	35
26	499963	6·32	977125	·70	522838	7·02	477162	34
27	500342	6·31	977083	·70	523259	7·01	476741	33
28	500721	6·31	977041	·70	523680	7·01	476320	32
29	501099	6·30	976999	·70	524100	7·00	475900	31
30	501476	6·29	976957	·70	524520	6·99	475480	30
31	9·501854	6·29	9·976914	·70	9·524939	6·99	10·475061	29
32	502231	6·28	976872	·71	525359	6·98	474641	28
33	502607	6·28	976830	·71	525778	6·98	474222	27
34	502984	6·27	976787	·71	526197	6·97	473803	26
35	503360	6·26	976745	·71	526615	6·97	473385	25
36	503735	6·26	976702	·71	527033	6·96	472967	24
37	504110	6·25	976660	·71	527451	6·96	472549	23
38	504485	6·25	976617	·71	527868	6·95	472132	22
39	504860	6·24	976574	·71	528285	6·95	471715	21
40	505234	6·23	976532	·71	528702	6·94	471298	20
41	9·505608	6·23	9·976489	·71	9·529119	6·93	10·470881	19
42	505981	6·22	976446	·71	529535	6·93	470465	18
43	506354	6·22	976404	·71	529950	6·93	470050	17
44	506727	6·21	976361	·71	530366	6·92	469634	16
45	507099	6·20	676318	·71	530781	6·91	469219	15
46	507471	6·20	976275	·71	531196	6·91	468804	14
47	507843	6·19	976232	·72	531611	6·90	468389	13
48	508214	6·19	976189	·72	532025	6·90	467975	12
49	508585	6·18	976146	·72	532439	6·89	467561	11
50	508956	6·18	976103	·72	532853	6·89	467147	10
51	9·509326	6·17	9·976060	·72	9·533266	6·88	10·466734	9
52	509696	6·16	976017	·72	533679	6·88	466321	8
53	510065	6·16	975974	·72	534092	6·87	465908	7
54	510434	6·15	975930	·72	534504	6·87	465496	6
55	510803	6·15	975887	·72	534916	6·86	465084	5
56	511172	6·14	975844	·72	535328	6·86	464672	4
57	511540	6·13	975800	·72	535739	6·85	464261	3
58	511907	6·13	975757	·72	536150	6·85	463850	2
59	512275	6·12	975714	·72	536561	6·84	463439	1
60	512642	6·12	975670	·72	536972	6·84	463028	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
9·412996	7·85	9·984944	·57	9·428052	8·42	10·571948	60
413467	7·84	984910	·57	428557	8·41	571443	59
413938	7·83	984876	·57	429062	8·40	570938	58
414408	7·83	984842	·57	429566	8·39	570434	57
414878	7·82	984808	·57	430070	8·38	569930	56
415347	7·81	984774	·57	430573	8·38	569427	55
415815	7·80	984740	·57	431075	8·37	568925	54
416283	7·79	984706	·57	431577	8·36	568423	53
416751	7·78	984672	·57	432079	8·35	567921	52
417217	7·77	984637	·57	432580	8·34	567420	51
417684	7·76	984603	·57	433080	8·33	566920	50
9·418150	7·75	9·984569	·57	9·433580	8·32	10·566420	49
418615	7·74	984535	·57	434080	8·32	565920	48
419079	7·73	984500	·57	434579	8·31	565421	47
419544	7·73	984466	·57	435078	8·30	564922	46
420007	7·72	984432	·58	435576	8·29	564424	45
420470	7·71	984397	·58	436073	8·28	563927	44
420933	7·70	984363	·58	436570	8·28	563430	43
421395	7·69	984328	·58	437067	8·27	562933	42
421857	7·68	984294	·58	437563	8·26	562437	41
422318	7·67	984259	·58	438059	8·25	561941	40
9·422778	7·67	9·984224	·58	9·438554	8·24	10·561446	39
423238	7·66	984190	·58	439048	8·23	560952	38
423697	7·65	984155	·58	439543	8·23	560457	37
424156	7·64	984120	·58	440036	8·22	559964	36
424615	7·63	984085	·58	440529	8·21	559471	35
425073	7·62	984050	·58	441022	8·20	558978	34
425530	7·61	984015	·58	441514	8·19	558486	33
425987	7·60	983981	·58	442006	8·19	557994	32
426443	7·60	983946	·58	442497	8·18	557503	31
426899	7·59	983911	·58	442988	8·17	557012	30
9·427354	7·58	9·983875	·58	9·443479	8·16	10·556521	29
427809	7·57	983840	·59	443968	8·16	556032	28
428263	7·56	983805	·59	444458	8·15	555542	27
428717	7·55	983770	·59	444947	8·14	555053	26
429170	7·54	983735	·59	445435	8·13	554565	25
429623	7·53	983700	·59	445923	8·12	554077	24
430075	7·52	983664	·59	446411	8·12	553589	23
430527	7·52	983629	·59	446898	8·11	553102	22
430978	7·51	983594	·59	447384	8·10	552616	21
431429	7·50	983558	·59	447870	8·09	552130	20
9·431879	7·49	9·983523	·59	9·448356	8·09	10·551644	19
432329	7·49	983487	·59	448841	8·08	551159	18
432778	7·48	983452	·59	449326	8·07	550674	17
433226	7·47	983416	·59	449810	8·06	550190	16
433675	7·46	983381	·59	450294	8·06	549706	15
434122	7·45	983345	·59	450777	8·05	549223	14
434569	7·44	983309	·59	451260	8·04	548740	13
435016	7·44	983273	·60	451743	8·03	548257	12
435462	7·43	983238	·60	452225	8·02	547775	11
435908	7·42	983202	·60	452706	8·02	547294	10
9·436353	7·41	9·983166	·60	9·453187	8·01	10·546813	9
436798	7·40	983130	·60	453668	8·00	546332	8
437242	7·40	983094	·60	454148	7·99	545852	7
437686	7·39	983058	·60	454628	7·99	545372	6
438129	7·38	983022	·60	455107	7·98	544893	5
438572	7·37	982986	·60	455586	7·97	544414	4
439014	7·36	982950	·60	456064	7·96	543936	3
439456	7·36	982914	·60	456542	7·96	543458	2
439897	7·35	982878	·60	457019	7·95	542981	
440338	7·34	982842	·60	457496	7·94	542504	
Cosine	D.	Sine		Cotang.	D.	Tang.	

(74 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·440338	7·34	9·982842	·60	9·457496	7·94	10·542504	60
1	440778	7·33	982805	·60	457973	7·93	542027	59
2	441218	7·32	982769	·61	458449	7·93	541551	58
3	441658	7·31	982733	·61	458925	7·92	541075	57
4	442096	7·31	982696	·61	459400	7·91	540600	56
5	442535	7·30	982660	·61	459875	7·90	540125	55
6	442973	7·29	982624	·61	460349	7·90	539651	54
7	443410	7·28	982587	·61	460823	7·89	539177	53
8	443847	7·27	982551	·61	461297	7·88	538703	52
9	444284	7·27	982514	·61	461770	7·88	538230	51
10	444720	7·26	982477	·61	462242	7·87	537758	50
11	9·445155	7·25	9·982441	·61	9·462714	7·86	10·537286	49
12	445590	7·24	982404	·61	463186	7·85	536814	48
13	446025	7·23	982367	·61	463658	7·85	536342	47
14	446459	7·23	982331	·61	464129	7·84	535871	46
15	446893	7·22	982294	·61	464599	7·83	535401	45
16	447326	7·21	982257	·61	465069	7·83	534931	44
17	447759	7·20	982220	·62	465539	7·82	534461	43
18	448191	7·20	982183	·62	466008	7·81	533992	42
19	448623	7·19	982146	·62	466476	7·80	533524	41
20	449054	7·18	982109	·62	466945	7·80	533055	40
21	9·449485	7·17	9·982072	·62	9·467413	7·79	10·532587	39
22	449915	7·16	982035	·62	467880	7·78	532120	38
23	450345	7·16	981998	·62	468347	7·78	531653	37
24	450775	7·15	981961	·62	468814	7·77	531186	36
25	451204	7·14	981924	·62	469280	7·76	530720	35
26	451632	7·13	981886	·62	469746	7·75	530254	34
27	452060	7·13	981849	·62	470211	7·75	529789	33
28	452488	7·12	981812	·62	470676	7·74	529324	32
29	452915	7·11	981774	·62	471141	7·73	528859	31
30	453342	7·10	981737	·62	471605	7·73	528395	30
31	9·453768	7·10	9·981699	·63	9·472068	7·72	10·527932	29
32	454194	7·09	981662	·63	472532	7·71	527468	28
33	454619	7·08	981625	·63	472995	7·71	527005	27
34	455044	7·07	981587	·63	473457	7·70	526543	26
35	455469	7·07	981549	·63	473919	7·69	526081	25
36	455893	7·06	981512	·63	474381	7·69	525619	24
37	456316	7·05	981474	·63	474842	7·68	525158	23
38	456739	7·04	981436	·63	475303	7·67	524697	22
39	457162	7·04	981399	·63	475763	7·67	524237	21
40	457584	7·03	981361	·63	476223	7·66	523777	20
41	9·458006	7·02	9·981323	·63	9·476683	7·65	10·523317	19
42	458427	7·01	981285	·63	477142	7·65	522858	18
43	458848	7·01	981247	·63	477601	7·64	522399	17
44	459268	7·00	981209	·63	478059	7·63	521941	16
45	459688	6·99	981171	·63	478517	7·63	521483	15
46	460108	6·98	981133	·64	478975	7·62	521025	14
47	460527	6·98	981095	·64	479432	7·61	520568	13
48	460946	6·97	981057	·64	479889	7·61	520111	12
49	461364	6·96	981019	·64	480345	7·60	519655	11
50	461782	6·95	980981	·64	480801	7·59	519199	10
51	9·462199	6·95	9·980942	·64	9·481257	7·59	10·518743	9
52	462616	6·94	980904	·64	481712	7·58	518288	8
53	463032	6·93	980866	·64	482167	7·57	517833	7
54	463448	6·93	980827	·64	482621	7·57	517379	6
55	463864	6·92	980789	·64	483075	7·56	516925	5
56	464279	6·91	980750	·64	483529	7·55	516471	4
57	464694	6·90	980712	·64	483982	7·55	516018	3
58	465108	6·90	980673	·64	484435	7·54	515565	2
59	465522	6·89	980635	·64	484887	7·53	515113	1
60	465935	6·88	980596	·64	485339	7·53	514661	0
	Cosine	D.	Sine		Cotang.	D.	Tang.	M.

(73 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·465935	6·88	9·980596	·64	9·485339	7·55	10·514661	60
1	466348	6·88	980558	·64	485791	7·52	514209	59
2	466761	6·87	980519	·65	486242	7·51	513758	58
3	467173	6·86	980480	·65	486693	7·51	513307	57
4	467585	6·85	980442	·65	487143	7·50	512857	56
5	467996	6·85	980403	·65	487593	7·49	512407	55
6	468407	6·84	980364	·65	488043	7·49	511957	54
7	468817	6·83	980325	·65	488492	7·48	511508	53
8	469227	6·83	980286	·65	488941	7·47	511059	52
9	469637	6·82	980247	·65	489390	7·47	510610	51
10	470046	6·81	980208	·65	489838	7·46	510162	50
11	9·470455	6·80	9·980169	·65	9·490286	7·46	10·509714	49
12	470863	6·80	980130	·65	490733	7·45	509267	48
13	471271	6·79	980091	·65	491180	7·44	508820	47
14	471679	6·78	980052	·65	491627	7·44	508373	46
15	472086	6·78	980012	·65	492073	7·43	507927	45
16	472492	6·77	979973	·65	492519	7·43	507481	44
17	472898	6·76	979934	·66	492965	7·42	507035	43
18	473304	6·76	979895	·66	493410	7·41	506590	42
19	473710	6·75	979855	·66	493854	7·40	506146	41
20	474115	6·74	979816	·66	494299	7·40	505701	40
21	9·474519	6·74	9·979776	·66	9·494743	7·40	10·505257	39
22	474923	6·73	979737	·66	495186	7·39	504814	38
23	475327	6·72	979697	·66	495630	7·38	504370	37
24	475730	6·72	979658	·66	496073	7·37	503927	36
25	476133	6·71	979618	·66	496515	7·37	503485	35
26	476536	6·70	979579	·66	496957	7·36	503043	34
27	476938	6·69	979539	·66	497399	7·36	502601	33
28	477340	6·69	979499	·66	497841	7·35	502159	32
29	477741	6·68	979459	·66	498282	7·34	501718	31
30	478142	6·67	979420	·66	498722	7·34	501278	30
31	9·478542	6·67	9·979380	·66	9·499163	7·33	10·500837	29
32	478942	6·66	979340	·66	499603	7·33	500397	28
33	479342	6·65	979300	·67	500042	7·32	499958	27
34	479741	6·65	979260	·67	500481	7·31	499519	26
35	480140	6·64	979220	·67	500920	7·31	499080	25
36	480539	6·63	979180	·67	501359	7·30	498641	24
37	480937	6·63	979140	·67	501797	7·30	498203	23
38	481334	6·62	979100	·67	502235	7·29	497765	22
39	481731	6·61	979059	·67	502672	7·28	497328	21
40	482128	6·61	979019	·67	503109	7·28	496891	20
41	9·482525	6·60	9·978979	·67	9·503546	7·27	10·496454	19
42	482921	6·59	978939	·67	503982	7·27	496018	18
43	483316	6·59	978898	·67	504418	7·26	495582	17
44	483712	6·58	978858	·67	504854	7·25	495146	16
45	484107	6·57	978817	·67	505289	7·25	494711	15
46	484501	6·57	978777	·67	505724	7·24	494275	14
47	484895	6·56	978736	67	506159	7·24	493841	13
48	485289	6·55	978696	·68	506593	7·23	493407	12
49	485682	6·55	978655	·68	507027	7·22	492973	11
50	486075	6·54	978615	·68	507460	7·22	492540	10
51	9·486467	6·53	9·978574	·68	9·507893	7·21	10·492107	9
52	486860	6·53	978533	·68	508326	7·21	491674	8
53	487251	6·52	978493	·68	508759	7·20	491241	7
54	487643	6·51	978452	·68	509191	7·19	490809	6
55	488034	6·51	978411	·68	509622	7·19	490378	5
56	488424	6·50	978370	·68	510054	7·18	489946	4
57	488814	6·50	978329	·68	510485	7·18	489515	3
58	489204	6·49	978288	·68	510916	7·17	489084	2
59	489593	6·48	978247	·68	511346	7·16	488654	1
60	489982	6·48	978206	·68	511776	7·16	[illegible]	[illegible]
	Cosine	D.	Sine	D.	Cotang.	D.	[illegible]	

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·489982	6·48	9·978206	·68	9·511776	7·16	10·488224	60
1	490371	6·48	978165	·68	512206	7·16	487794	59
2	490759	6·47	978124	·68	512635	7·15	487365	58
3	491147	6·46	978083	·69	513064	7·14	486936	57
4	491535	6·46	978042	·69	513493	7·14	486507	56
5	491922	6·45	978001	·69	513921	7·13	486079	55
6	492308	6·44	977959	·69	514349	7·13	485651	54
7	492695	6·44	977918	·69	514777	7·12	485223	53
8	493081	6·43	977877	·69	515204	7·12	484796	52
9	493466	6·42	977835	·69	515631	7·11	484369	51
10	493851	6·42	977794	·69	516057	7·10	483943	50
11	9·494236	6·41	9·977752	·69	9·516484	7·10	10·483516	49
12	494621	5·41	977711	·69	516910	7·09	483090	48
13	495005	6·40	977669	·69	517335	7·09	482665	47
14	495388	6·39	977628	·69	517761	7·08	482239	46
15	495772	6·39	977586	·69	518185	7·08	481815	45
16	496154	6·38	977544	·70	518610	7·07	481390	44
17	496537	6·37	977503	·70	519034	7·06	480966	43
18	496919	6·37	977461	·70	519458	7·06	480542	42
19	497301	6·36	977419	·70	519882	7·05	480118	41
20	497682	6·36	977377	·70	520305	7·05	479695	40
21	9·498064	6·35	9·977335	·70	9·520728	7·04	10·479272	39
22	498444	6·34	977293	·70	521151	7·03	478849	38
23	498825	6·34	977251	·70	521573	7·03	478427	37
24	499204	6·33	977209	·70	521995	7·03	478005	36
25	499584	6·32	977167	·70	522417	7·02	477583	35
26	499963	6·32	977125	·70	522838	7·02	477162	34
27	500342	6·31	977083	·70	523259	7·01	476741	33
28	500721	6·31	977041	·70	523680	7·01	476320	32
29	501099	6·30	976999	·70	524100	7·00	475900	31
30	501476	6·29	976957	·70	524520	6·99	475480	30
31	9·501854	6·29	9·976914	·70	9·524939	6·99	10·475061	29
32	502231	6·28	976872	·71	525359	6·98	474641	28
33	502607	6·28	976830	·71	525778	6·98	474222	27
34	502984	6·27	976787	·71	526197	6·97	473803	26
35	503360	6·26	976745	·71	526615	6·97	473385	25
36	503735	6·26	976702	·71	527033	6·96	472967	24
37	504110	6·25	976660	·71	527451	6·96	472549	23
38	504485	6·25	976617	·71	527868	6·95	472132	22
39	504860	6·24	976574	·71	528285	6·95	471715	21
40	505234	6·23	976532	·71	528702	6·94	471298	20
41	9·505608	6·23	9·976489	·71	9·529119	6·93	10·470881	19
42	505981	6·22	976446	·71	529535	6·93	470465	18
43	506354	6·22	976404	·71	529950	6·93	470050	17
44	506727	6·21	976361	·71	530366	6·92	469634	16
45	507099	6·20	676318	·71	530781	6·91	469219	15
46	507471	6·20	976275	·71	531196	6·91	468804	14
47	507843	6·19	976232	·72	531611	6·90	468389	13
48	508214	6·19	976189	72	532025	6·90	467975	12
49	508585	6·18	976146	·72	532439	6·89	467561	11
50	508956	6·18	976103	·72	532853	6·89	467147	10
51	9·509326	6·17	9·976060	·72	9·533266	6·88	10·466734	9
52	509696	6·16	976017	·72	533679	5·88	466321	8
53	510065	6·16	975974	·72	534092	6·87	465908	7
54	510434	6·15	975930	·72	534504	6·87	465496	6
55	510803	6·15	975887	·72	534916	6·86	465084	5
56	511172	6·14	975844	·72	535328	6·86	464672	4
57	511540	6·13	975800	·72	535739	6·85	464261	3
58	511907	6·13	975757	·72	536150	6·85	463850	2
59	512275	6·12	975714	·72	536561	6·84	463439	1
60	512642	6·12	975670	·72	536972	6·84	463028	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

(71 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·512642	6·12	9·975670	·73	9·536972	6·84	10·463028	60
1	513009	6·11	975627	·73	537382	6·83	462618	59
2	513375	6·11	975583	·73	537792	6·83	462208	58
3	513741	6·10	975539	·73	538202	6·82	461798	57
4	514107	6·09	975496	·73	538611	6·82	461389	56
5	514472	6·09	975452	·73	539020	6·81	460980	55
6	514837	6·08	975408	·73	539429	6·81	460571	54
7	515202	6·08	975365	·73	539837	6·80	460163	53
8	515566	6·07	975321	·73	540245	6·80	459755	52
9	515930	6·07	975277	·73	540653	6·79	459347	51
10	516294	6·06	975233	·73	541061	6·79	458939	50
11	9·516657	6·05	9·975189	·73	9·541468	6·78	10·458532	49
12	517020	6·05	975145	·73	541875	6·78	458125	48
13	517382	6·04	975101	·73	542281	6·77	457719	47
14	517745	6·04	975057	·73	542688	6·77	457312	46
15	518107	6·03	975013	·73	543094	6·76	456906	45
16	518468	6·03	974969	·74	543499	6·76	456501	44
17	518829	6·02	974925	·74	543905	6·75	456095	43
18	519190	6·01	974880	·74	544310	6·75	455690	42
19	519551	6·01	974836	·74	544715	6·74	455285	41
20	519911	6·00	974792	·74	545119	6·74	454881	40
21	9·520271	6·00	9·974748	·74	9·545524	6·73	10·454476	39
22	520631	5·99	974703	·74	545928	6·73	454072	38
23	520990	5·99	974659	·74	546331	6·72	453669	37
24	521349	5·98	974614	·74	546735	6·72	453265	36
25	521707	5·98	974570	·74	547138	6·71	452862	35
26	522066	5·97	974525	·74	547540	6·71	452460	34
27	522424	5·96	974481	·74	547943	6·70	452057	33
28	522781	5·96	974436	·74	548345	6·70	451655	32
29	523138	5·95	974391	·74	548747	6·69	451253	31
30	523495	5·95	974347	·75	549149	6·69	450851	30
31	9·523852	5·94	9·974302	·75	9·549550	6·68	10·450450	29
32	524208	5·94	974257	·75	549951	6·68	450049	28
33	524564	5·93	974212	·75	550352	6·67	449648	27
34	524920	5·93	974167	·75	550752	6·67	449248	26
35	525275	5·92	974122	·75	551152	6·66	448848	25
36	525630	5·91	974077	·75	551552	6·66	448448	24
37	525984	5·91	974032	·75	551952	6·65	448048	23
38	526339	5·90	973987	·75	552351	6·65	447649	22
39	526693	5·90	973942	·75	552750	6·65	447250	21
40	527046	5·89	973897	·75	553149	6·64	446851	20
41	9·527400	5·89	9·973852	·75	9·553548	6·64	10·446452	19
42	527753	5·88	973807	·75	553946	6·63	446054	18
43	528105	5·88	973761	·75	554344	6·63	445656	17
44	528458	5·87	973716	·76	554741	6·62	445259	16
45	528810	5·87	973671	·76	555139	6·62	444861	15
46	529161	5·86	973625	·76	555536	6·61	444464	14
47	529513	5·86	973580	·76	555933	6·61	444067	13
48	529864	5·85	973535	·76	556329	6·60	443671	12
49	530215	5·85	973489	·76	556725	6·60	443275	11
50	530565	5·84	973444	·76	557121	6·59	442879	10
51	9·530915	5·84	9·973398	·76	9·557517	6·59	10·442483	9
52	531265	5·83	973352	·76	557913	6·59	442087	8
53	531614	5·82	973307	·76	558308	6·58	441692	7
54	531963	5·82	973261	·76	558702	6·58	441298	6
55	532312	5·81	973215	·76	559097	5·57	440903	5
56	532661	5·81	973169	·76	559491	5·57	440509	4
57	533009	5·80	973124	·76	559885	6·56	440115	3
58	533357	5·80	973078	·76	560279	6·56	439721	2
59	533704	5·79	973032	·77	560673	6·55	439327	1
60	534052	5·78	972986	·77	561066	6·55	438934	0
M.	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

(70 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·534052	5·78	9·972986	·77	9·561066	6·55	10·438934	60
1	534399	5·77	972940	·77	561459	6·54	438541	59
2	534745	5·77	972894	·77	561851	6·54	438149	58
3	535092	5·77	972848	·77	562244	6·53	437756	57
4	535438	5·76	972802	·77	562636	6·53	437364	56
5	535783	5·76	972755	·77	563028	6·53	436972	55
6	536129	5·75	972709	·77	563419	6·52	436581	54
7	536474	5·74	972663	·77	563811	6·52	436189	53
8	536818	5·74	972617	·77	564202	6·51	435798	52
9	537163	5·73	972570	·77	564592	6·51	435408	51
10	537507	5·73	972524	·77	564983	6·50	435017	50
11	9·537851	5·72	9·972478	·77	9·565373	6·50	10·434627	49
12	538194	5·72	972431	·78	565763	6·49	434237	48
13	538538	5·71	972385	·78	566153	6·49	433847	47
14	538880	5·71	972338	·78	566542	5·49	433458	46
15	539223	5·70	972291	·78	566932	6·48	433068	45
16	539565	5·70	972245	·78	567320	5·48	432680	44
17	539907	5·69	972198	·78	567709	6·47	432291	43
18	540249	5·69	972151	·78	568098	5·47	431902	42
19	540590	5·68	972105	·78	568486	6·46	431514	41
20	540931	5·68	972058	·78	568873	6·46	431127	40
21	9·541272	5·67	9·972011	·78	9·569261	6·45	10·430739	39
22	541613	5·67	971964	·78	569648	6·45	430352	38
23	541953	5·66	971917	·78	570035	6·45	429965	37
24	542293	5·66	971870	·78	570422	6·44	429578	36
25	542632	5·65	971823	·78	570809	6·44	429191	35
26	542971	5·65	971776	·78	571195	6·43	428805	34
27	543310	5·64	971729	·79	571581	6·43	428419	33
28	543649	5·64	971682	·79	571967	6·42	428033	32
29	543987	5·63	971635	·79	572352	6·42	427648	31
30	544325	5·63	971588	·79	572738	6·42	427262	30
31	9·544663	5·62	9·971540	·79	9·573123	6·41	10·426877	29
32	545000	5·62	971493	·79	573507	6·41	426493	28
33	545338	5·61	971446	·79	573892	6·40	426108	27
34	545674	5·61	971398	·79	574276	6·40	425724	26
35	546011	5·60	971351	·79	574660	6·39	425340	25
36	546347	5·60	971303	·79	575044	6·39	424956	24
37	546683	5·59	971256	·79	575427	6·39	424573	23
38	547019	5·59	971208	·79	575810	6·38	424190	22
39	547354	5·58	971161	·79	576193	6·38	423807	21
40	547689	5·58	971113	·79	576576	6·37	423424	20
41	9·548024	5·57	9·971066	·80	9·576958	6·37	10·423041	19
42	548359	5·57	971018	·80	577341	6·36	422659	18
43	548693	5·56	970970	·80	577723	6·36	422277	17
44	549027	5·56	970922	·80	578104	6·36	421896	16
45	549360	5·55	970874	·80	578486	6·35	421514	15
46	549693	5·55	970827	·80	578867	6·35	421133	14
47	550026	5·54	970779	·80	579248	6·34	420752	13
48	550359	5·54	970731	·80	579629	6·34	420371	12
49	550692	5·53	970683	·80	580009	6·34	419991	11
50	551024	5·53	970635	·80	580389	6·33	419611	10
51	9·551356	5·52	9·970586	·80	9·580769	6·33	10·419231	9
52	551687	5·52	970538	·80	581149	6·32	418851	8
53	552018	5·52	970490	·80	581528	6·32	418472	7
54	552349	5·51	970442	·80	581907	6·32	418093	6
55	552680	5·51	970394	·80	582286	6·31	417714	5
56	553010	5·50	970345	·81	582665	6·31	417335	4
57	553341	5·50	970297	·81	583043	6·30	416957	3
58	553670	5·49	970249	·81	583422	6·30	416578	2
59	554000	5·49	970200	·81	583800	6·29	416200	1
60	554329	5·48	970152	·81	584177	6·29	415823	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
9·554329	5·48	9·970152	·81	9·584177	6·29	10·415823	60
554658	5·48	970103	·81	584555	6·29	415445	59
554987	5·47	970055	·81	584932	5·28	415068	58
555315	5·47	970006	·81	585309	6·28	414691	57
555643	5·46	969957	·81	585686	6·27	414314	56
555971	5·46	969909	·81	586062	6·27	413938	55
556299	5·45	969860	·81	586439	6·27	413561	54
556626	5·45	969811	·81	586815	6·26	413185	53
556953	5·44	969762	·81	587190	6·26	412810	52
557280	5·44	969714	·81	587566	6·25	412434	51
557606	5·43	969665	·81	587941	6·25	412059	50
9·557932	5·43	9·969616	·82	9·588316	6·25	10 411684	49
558258	5·43	969567	·82	588691	6·24	411309	48
558583	5·42	969518	·82	589066	6·24	410934	47
558909	5·42	969469	·82	589440	6·23	410560	46
559234	5·41	969420	·82	589814	6·23	410186	45
559558	5·41	969370	·82	590188	6·23	409812	44
559883	5·40	969321	·82	590562	6·22	409438	43
560207	5·40	969272	·82	590935	6·22	409065	42
560531	5·39	969223	·82	591308	6·22	408692	41
560855	5·39	969173	·82	591681	6·21	408319	40
9·561178	5·38	9·969124	·82	9 592054	6·21	10·407946	39
561501	5·38	969075	·82	592426	6·20	407574	38
561824	5·37	969025	·82	592798	6·20	407202	37
562146	5·37	968976	·82	593170	6·19	406829	36
562468	5·36	968926	·83	593542	6·19	406458	35
562790	5·36	968877	·83	593914	6·18	406086	34
563112	5·36	968827	·83	594285	6·18	405715	33
563433	5·35	968777	·83	594656	6·18	405344	32
563755	5·35	968728	·83	595027	6·17	404973	31
564075	5·34	968678	·83	595398	6·17	404602	30
9·564396	5·34	9·968628	·83	9·595768	6·17	10·404232	29
564716	5·33	968578	·83	596138	6·16	403862	28
565036	5·33	968528	·83	596508	6·16	403492	27
565356	5·32	968479	·83	596878	6·16	403122	26
565676	5·32	968429	·83	597247	6·15	402753	25
565995	5·31	968379	·83	597616	6·15	402384	24
566314	5·31	968329	·83	597985	6·15	402015	23
566632	5·31	968278	·83	598354	6·14	401646	22
566951	5·30	968228	·84	598722	6·14	401278	21
567269	5·30	968178	·84	599091	6·13	400909	20
9·567587	5·29	9·968128	·84	9·599459	6·13	10·400541	19
567904	5·29	968078	·84	599827	6·13	400173	18
568222	5·28	968027	·84	600194	6·12	399806	17
568539	5·28	967977	·84	600562	6·12	399438	16
568856	5·28	967927	·84	600929	6·11	399071	15
569172	5·27	967876	·84	601296	6·11	398704	14
569488	5·27	967826	·84	601662	6·11	398338	13
569804	5·26	967775	·84	602029	6·10	397971	12
570120	5·26	967725	·84	602395	6·10	397605	11
570435	5·25	967674	·84	602761	6·10	397239	10
9·570751	5·25	9·967624	·84	9·603127	6·09	10·396873	9
571066	5·24	967573	·84	603493	6·09	396507	8
571380	5·24	967522	·85	603858	6·09	396142	7
571695	5·23	967471	·85	604223	6·08	395777	6
572009	5·23	967421	·85	604588	6·08	395412	5
572323	5·23	967370	·85	504953	6·07	395047	4
572636	5·22	967319	·85	605317	6·07	394683	3
572950	5·22	967268	·85	605682	6·07	394318	2
573263	5·21	967217	·85	606046	6·06	393954	1
573575	5·21	967166	·85	606410	6·06	393590	0
Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M

(68 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·573575	5·21	9·967166	·85	9·606410	6·06	10·393590	60
1	573888	5·20	967115	·85	606773	6·06	393227	59
2	574200	5·20	967064	·85	607137	6·05	392863	58
3	574512	5·19	967013	·85	607500	6·05	392500	57
4	574824	5·19	966961	·85	607863	6·04	392137	56
5	575136	5·19	966910	·85	608225	6·04	391775	55
6	575447	5·18	966859	·85	608588	6·04	391412	54
7	575758	5·18	966808	·85	608950	6·03	391050	53
8	576069	5·17	966756	·86	609312	5·03	390688	52
9	576379	5·17	966705	·86	609674	6·03	390326	51
10	576689	5·16	966653	·86	610036	6·02	389964	50
11	9·576999	5·16	9·966602	·86	9·610397	6·02	10·389603	49
12	577309	5·16	966550	·86	610759	6·02	389241	48
13	577618	5·15	966499	·86	611120	6·01	388880	47
14	577927	5·15	966447	·86	611480	6·01	388520	46
15	578236	5·14	966395	·86	611841	6·01	388159	45
16	578545	5·14	966344	·86	612201	6·00	387799	44
17	578853	5·13	966292	·86	612561	6·00	387439	43
18	579162	5·13	966240	·86	612921	6·00	387079	42
19	579470	5·13	966188	·86	613281	5·99	386719	41
20	579777	5·12	966136	·86	613641	5·99	386359	40
21	9·580085	5·12	9·966085	·87	9·614000	5·98	10·386000	39
22	580392	5·11	966033	·87	614359	5·98	385641	38
23	580699	5·11	965981	·87	614718	5·98	385282	37
24	581005	5·11	965928	·87	615077	5·97	384923	36
25	581312	5·10	965876	·87	615435	5·97	384565	35
26	581618	5·10	965824	·87	615793	5·97	384207	34
27	581924	5·09	965772	·87	616151	5·96	383849	33
28	582229	5·09	965720	·87	616509	5·96	383491	32
29	582535	5·09	965668	·87	616867	5·96	383133	31
30	582840	5·08	965615	·87	617224	5·95	382776	30
31	9·583145	5·08	9·965563	·87	9·617582	5·95	10·382418	29
32	583449	5·07	965511	·87	617939	5·95	382061	28
33	583754	5·07	965458	·87	618295	5·94	381705	27
34	584058	5·06	965406	·87	618652	5·94	381348	26
35	584361	5·06	965353	·88	619008	5·94	380992	25
36	584665	5·06	965301	·88	619364	5·93	380636	24
37	584968	5·05	965248	·88	619721	5·93	380279	23
38	585272	5·05	965195	·88	620076	5·93	379924	22
39	585574	5·04	965143	·88	620432	5·92	379568	21
40	585877	5·04	965090	·88	620787	5·92	379213	20
41	9·586179	5·03	9·965037	·88	9·621142	5·92	10·378858	19
42	586482	5·03	964984	·88	621497	5·91	378503	18
43	586783	5·03	964931	·88	621852	5·91	378148	17
44	587085	5·02	964879	·88	622207	5·90	377793	16
45	587386	5·02	964826	·88	622561	5·90	377439	15
46	587688	5·01	964773	·88	622915	5·90	377085	14
47	587989	5·01	964719	·88	623269	5·89	376731	13
48	588289	5·01	964666	·89	623623	5·89	376377	12
49	588590	5·00	964613	·89	623976	5·89	376024	11
50	588890	5·00	964560	·89	624330	5·88	375670	10
51	9·589190	4·99	9·964507	·89	9·624683	5·88	10·375317	9
52	589489	4·99	964454	·89	625036	5·88	374964	8
53	589789	4·99	964400	·89	625388	5·87	374612	7
54	590088	4·98	964347	·89	625741	5·87	374259	6
55	590387	4·98	964294	·89	626093	5·87	373907	5
56	590686	4·97	964240	·89	626445	5·86	373555	4
57	590984	4·97	964187	·89	626797	5·86	373203	3
58	591282	4·97	964133	·89	627149	5·86	372851	2
59	591580	4·96	964080	·89	627501	5·85	372499	1
60	591878	4·96	964026	·89	627852	5·85	372148	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

(67 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·591878	4·96	9·964026	·89	9·627852	5·85	10·372148	60
1	592176	4·95	963972	·89	628203	5·85	371797	59
2	592473	4·95	963919	·89	628554	5·85	371446	58
3	592770	4·95	963865	·90	628905	5·84	371095	57
4	593067	4·94	963811	90	629255	5·84	370745	56
5	593363	4·94	963757	90	629606	5·83	370394	55
6	593659	4·93	963704	·90	629956	5·83	370044	54
7	593955	4·93	963650	·90	630306	5·82	369694	53
8	594251	4·93	963596	·90	630656	5·83	369344	52
9	594547	4·92	963542	·90	631005	5·82	368995	51
10	594842	4·92	963488	·90	631355	5·82	368645	50
11	9 595137	4·91	9·963434	·90	9·631704	5·82	10·368296	49
12	595432	4·91	963379	·90	632053	5·81	367947	48
13	595727	4·91	963325	·90	632401	5·81	367599	47
14	596021	4·90	963271	·90	632750	5·81	367250	46
15	596315	4·90	963217	·90	633098	5·80	366902	45
16	596609	4·89	963163	·90	633447	5·80	366553	44
17	596903	4·89	963108	·91	633795	5·80	366205	43
18	597196	4·89	963054	·91	634143	5·79	365857	42
19	597490	4·88	962999	·91	634490	5·79	365510	41
20	597783	4·88	962945	·91	634838	5·79	365162	40
21	9·598075	4·87	9·962890	·91	9·635185	5·78	10·364815	39
22	598368	4·87	962836	·91	635532	5·78	364468	38
23	598660	4·87	962781	·91	635879	5·78	364121	37
24	598952	4·86	962727	·91	636226	5·77	363774	36
25	599244	4·86	962672	·91	636572	5·77	363428	35
26	599536	4·85	962617	·91	636919	5·77	363081	34
27	599827	4·85	962562	·91	637265	5·77	362735	33
28	600118	4·85	962508	·91	637611	5·76	362389	32
29	600409	4·84	962453	·91	637956	5·76	362044	31
30	600700	4·84	962398	·92	638302	5·76	361698	30
31	9·600990	4·84	9·962343	·92	9·638647	5·75	10·361353	29
32	601280	4·83	962288	·92	638992	5·75	361008	28
33	601570	4·83	962233	·92	639337	5·75	360663	27
34	601860	4·82	962178	·92	639682	5·74	360318	26
35	602150	4·82	962123	·92	640027	5·74	359973	25
36	602439	4·82	962067	·92	640371	5·74	359629	24
37	602728	4·81	962012	·92	640716	5·73	359284	23
38	603017	4·81	961957	·92	641060	5·73	358940	22
39	603305	4·81	961902	·92	641404	5·73	358596	21
40	603594	4·80	961846	·92	641747	5·72	358253	20
41	9·603882	4·80	9·961791	·92	9·642091	5·72	10·357909	19
42	604170	4·79	961735	·92	642434	5·72	357566	18
43	604457	4·79	961680	·92	642777	5·72	357223	17
44	604745	4·79	961624	·93	643120	5·71	356880	16
45	605032	4·78	961569	·93	643463	5·71	3565[illegible]	15
46	605319	4·78	961513	·93	643806	5·71	356194	14
47	605606	4·78	961458	·93	644148	5·70	355852	13
48	605892	4·77	961402	·93	644490	5·70	355510	12
49	606179	4·77	961346	·93	644832	5·70	355168	11
50	606465	4·76	961290	·93	645174	5·69	354826	10
51	9·606751	4·76	9·961235	·93	9·645516	5·69	10·354484	9
52	607036	4·76	961179	·93	645857	5·69	354143	8
53	607322	4·75	961123	·93	646199	5·69	353801	7
54	607607	4·75	961067	93	646540	5·68		
55	607892	4·74	961011	·93	646881	5·68		
56	608177	4·74	960955	·93	647222	5·68		
57	608461	4·74	960899	·93	647562	5·67		
58	608745	4·73	960843	·94	647903	5		
59	609029	4·73	960786	·94	648243			
60	609313	4·73	960730	·94	648583			
	Cosine	D.	Sine	D.	Cotang.			

(66 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·609313	4·73	9·960730	·94	9·648583	5·66	10·351417	60
1	609597	4·72	960674	·94	648923	5·66	351077	59
2	609880	4·72	960618	·94	649263	5·66	350737	58
3	610164	4·72	960561	·94	649602	5·66	350398	57
4	610447	4·71	960505	·94	649942	5·65	350058	56
5	610729	4·71	960448	·94	650281	5·65	349719	55
6	611012	4·70	960392	·94	650620	5·65	349380	54
7	611294	4·70	960335	·94	650959	5·64	349041	53
8	611576	4·70	960279	·94	651297	5·64	348703	52
9	611858	4·69	960222	·94	651636	5·64	348364	51
10	612140	4·69	960165	·94	651974	5·63	348026	50
11	9·612421	4·69	9·960109	·95	9·652312	5·63	10·347688	49
12	612702	4·68	960052	·95	652650	5·63	347350	48
13	612983	4·68	959995	·95	652988	5·63	347012	47
14	613264	4·67	959938	·95	653326	5·62	346674	46
15	613545	4·67	959882	·95	653663	5·62	346337	45
16	613825	4·67	959825	·95	654000	5·62	346000	44
17	614105	4·66	959768	·95	654337	5·61	345663	43
18	614385	4·66	959711	·95	654674	5·61	345326	42
19	614665	4·66	959654	·95	655011	5·61	344989	41
20	614944	4·65	959596	·95	655348	5·61	344652	40
21	9·615223	4·65	9·959539	·95	9·655684	5·60	10·344316	39
22	615502	4·65	959482	·95	656020	5·60	343980	38
23	615781	4·64	959425	·95	656356	5·60	343644	37
24	616060	4·64	959368	·95	656692	5·59	343308	36
25	616338	4·64	959310	·96	657028	5·59	342972	35
26	616616	4·63	959253	·96	657364	5·59	342636	34
27	616894	4·63	959195	·96	657699	5·59	342301	33
28	617172	4·62	959138	·96	658034	5·58	341966	32
29	617450	4·62	959081	·96	658369	5·58	341631	31
30	617727	4·62	959023	·96	658704	5·58	341296	30
31	9·618004	4·61	9·958965	·96	9·659039	5·58	10·340961	29
32	618281	4·61	958908	·96	659373	5·57	340627	28
33	618558	4·61	958850	·96	659708	5·57	340292	27
34	618834	4·60	958792	·96	660042	5·57	339958	26
35	619110	4·60	958734	·96	660376	5·57	339624	25
36	619386	4·60	958677	·96	660710	5·56	339290	24
37	619662	4·59	958619	·96	661043	5·56	338957	23
38	619938	4·59	958561	·96	661377	5·56	338623	22
39	620213	4·59	958503	·97	661710	5·55	338290	21
40	620488	4·58	958445	·97	662043	5·55	337957	20
41	9·620763	4·58	9·958387	·97	9·662376	5·55	10·337624	19
42	621038	4·57	958329	·97	662709	5·54	337291	18
43	621313	4·57	958271	·97	663042	5·54	336958	17
44	621587	4·57	958213	·97	663375	5·54	336625	16
45	621861	4·56	958154	·97	663707	5·54	336293	15
46	622135	4·56	958096	·97	664039	5·53	335961	14
47	622409	4·56	958038	·97	664371	5·53	335629	13
48	622682	4·55	957979	·97	664703	5·53	335297	12
49	622956	4·55	957921	·97	665035	5·53	334965	11
50	623229	4·55	957863	·97	665366	5·52	334634	10
51	9·623502	4·54	9·957804	·97	9·665697	5·52	10·334303	9
52	623774	4·54	957746	·98	666029	5·52	333971	8
53	624047	4·54	957687	·98	666360	5·51	333640	7
54	624319	4·53	957628	·98	666691	5·51	333309	6
55	624591	4·53	957570	·98	667021	5·51	332979	5
56	624863	4·53	957511	·98	667352	5·51	332648	4
57	625135	4·52	957452	·98	667682	5·50	332318	3
58	625406	4·52	957393	·98	668013	5·50	331987	2
59	625677	4·52	957335	·98	668343	5·50	331657	1
60	625948	4·51	957276	·98	668672	5·50	331328	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

(65 DEGREES.)

Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
9·625948	4·51	9·957276	·98	9·668673	5·50	10·331327	60
626219	4·51	957217	·98	669002	5·49	330998	59
626490	4·51	957158	·98	669332	5·49	330668	58
626760	4·50	957099	·98	669661	5·49	330339	57
627030	4·50	957040	·98	669991	5·48	330009	56
627300	4·50	956981	·98	670320	5·48	329680	55
627570	4·49	956921	·99	670649	5·48	329351	54
627840	4·49	956862	·99	670977	5·48	329023	53
628109	4·49	956803	·99	671306	5·47	328694	52
628378	4·48	956744	·99	671634	5·47	328366	51
628647	4·48	956684	·99	671963	5·47	328037	50
9·628916	4·47	9·956625	·99	9·672291	5·47	10·327709	49
629185	4·47	956566	·99	672619	5·46	327381	48
629453	4·47	956506	·99	672947	5·46	327053	47
629721	4·46	956447	·99	673274	5·46	326726	46
629989	4·46	956387	·99	673602	5·46	326398	45
630257	4·46	956327	·99	673929	5·45	326071	44
630524	4·46	956268	·99	674257	5·45	325743	43
630792	4·45	956208	1·00	674584	5·45	325416	42
631059	4·45	956148	1·00	674910	5·44	325090	41
631326	4·45	956089	1·00	675237	5·44	324763	40
9·631593	4·44	9·956029	1·00	9·675564	5·44	10·324436	39
631859	4·44	955969	1·00	675890	5·44	324110	38
632125	4·44	955909	1·00	676216	5·43	323784	37
632392	4·43	955849	1·00	676543	5·43	323457	36
632658	4·43	955789	1·00	676869	5·43	323131	35
632923	4·43	955729	1·00	677194	5·43	322806	34
633189	4·42	955669	1·00	677520	5·42	322480	33
633454	4·42	955609	1·00	677846	5·42	322154	32
633719	4·42	955548	1·00	678171	5·42	321829	31
633984	4·41	955488	1·00	678496	5·42	321504	30
9·634249	4·41	9·955428	1·01	9·678821	5·41	10·321179	29
634514	4·40	955368	1·01	679146	5·41	320854	28
634778	4·40	955307	1·01	679471	5·41	320529	27
635042	4·40	955247	1·01	679795	5·41	320205	26
635306	4·39	955186	1·01	680120	5·40	319880	25
635570	4·39	955126	1·01	680444	5·40	319556	24
635834	4·39	955065	1·01	680768	5·40	319232	23
636097	4·38	955005	1·01	681092	5·40	318908	22
636360	4·38	954944	1·01	681416	5·39	318584	21
636623	4·38	954883	1·01	681740	5·39	318260	20
9·636886	4·37	9·954823	1·01	9·682063	5·39	10·317937	19
637148	4·37	954762	1·01	682387	5·39	317613	18
637411	4·37	954701	1·01	682710	5·38	317290	17
637673	4·37	954640	1·01	683033	5·38	316967	16
637935	4·36	954579	1·01	683356	5·38	316644	15
638197	4·36	954518	1·02	683679	5·38	316321	14
638458	4·36	954457	1·02	684001	5·37	315999	13
638720	4·35	954396	1·02	684324	5·37	315676	12
638981	4·35	954335	1·02	684646	5·37	315354	11
639242	4·35	954274	1·02	684968	5·37	315032	10
9·639503	4·34	9·954213	1·02	9·685290	5·36	10·314710	9
639764	4·34	954152	1·02	685612	5·36	314388	8
640024	4·34	954090	1·02	685934	5·36	314066	7
640284	4·33	954029	1·02	686255	5·36	313745	6
640544	4·33	953968	1·02	686577	5·35	313423	5
640804	4·33	953906	1·02	686898	5·35	313102	4
641064	4·32	953845	1·02	687219	5·35	312781	3
641324	4·32	953783	1·02	687540	5·35	312460	2
641584	4·32	953722	1·03	687861	5·34	312139	1
641842	4·31	953660	1·03	688182	5 34	311818	0
Cosine	D.	Sine	D.	Cotang.	D	Tang.	M.

(64 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·698970	3·64	9·937531	1·21	9·761439	4·86	10·238561	60
1	699189	3·64	937458	1·22	761731	4·86	238269	59
2	699407	3·64	937385	1·22	762023	4·86	237977	58
3	699626	3·64	937312	1·22	762314	4·86	237686	57
4	699844	3·63	937238	1·22	762606	4·85	237394	56
5	700062	3·63	937165	1·22	762897	4·85	237103	55
6	700280	3·63	937092	1·22	763188	4·85	236812	54
7	700498	3·63	937019	1·22	763479	4·85	236521	53
8	700716	3·63	936946	1·22	763770	4·85	236230	52
9	700933	3·62	936872	1·22	764061	4·85	235939	51
10	701151	3·62	936799	1·22	764352	4·84	235648	50
11	9·701368	3·62	9·936725	1·22	9·764643	4·84	10·235357	49
12	701585	3·62	936652	1·23	764933	4·84	235067	48
13	701802	3·61	936578	1·23	765224	4·84	234776	47
14	702019	3·61	936505	1·23	765514	4·84	234486	46
15	702236	3·61	936431	1·23	765805	4·84	234195	45
16	702452	3·61	936357	1·23	766095	4·84	233905	44
17	702669	3·60	936284	1·23	766385	4·83	233615	43
18	702885	3·60	936210	1·23	766675	4·83	233325	42
19	703101	3·60	936136	1·23	766965	4·83	233035	41
20	703317	3·60	936062	1·23	767255	4·83	232745	40
21	9·703533	3·59	9·935988	1·23	9·767545	4·83	10·232455	39
22	703749	3·59	935914	1·23	767834	4·83	232166	38
23	703964	3·59	935840	1·23	768124	4·82	231876	37
24	704179	3·59	935766	1·24	768413	4·82	231587	36
25	704395	3·59	935692	1·24	768703	4·82	231297	35
26	704610	3·58	935618	1·24	768992	4·82	231008	34
27	704825	3·58	935543	1·24	769281	4·82	230719	33
28	705040	3·58	935469	1·24	769570	4·82	230430	32
29	705254	3·58	935395	1·24	769860	4·81	230140	31
30	705469	3·57	935320	1·24	770148	4·81	229852	30
31	9·705683	3·57	9·935246	1·24	9·770437	4·81	10·229563	29
32	705898	3·57	935171	1·24	770726	4·81	229274	28
33	706112	3·57	935097	1·24	771015	4·81	228985	27
34	706326	3·56	935022	1·24	771303	4·81	228697	26
35	706539	3·56	934948	1·24	771592	4·81	228408	25
36	706753	3·56	934873	1·24	771880	4·80	228120	24
37	706967	3·56	934798	1·25	772168	4·80	227832	23
38	707180	3·55	934723	1·25	772457	4·80	227543	22
39	707393	3·55	934649	1·25	772745	4·80	227255	21
40	707606	3·55	934574	1·25	773033	4·80	226967	20
41	9·707819	3·55	9·934499	1·25	9·773321	4·80	10·226679	19
42	708032	3·54	934424	1·25	773608	4·79	226392	18
43	708245	3·54	934349	1·25	773896	4·79	226104	17
44	708458	3·54	934274	1·25	774184	4·79	225816	16
45	708670	3·54	934199	1·25	774471	4·79	225529	15
46	708882	3·53	934123	1·25	774759	4·79	225241	14
47	709094	3·53	934048	1·25	775046	4·79	224954	13
48	709306	3·53	933973	1·25	775333	4·79	224667	12
49	709518	3·53	933898	1·26	775621	4·78	224379	11
50	709730	3·53	933822	1·26	775908	4·78	224092	10
51	9·709941	3·52	9·933747	1·26	9·776195	4·78	10·223805	9
52	710153	3·52	933671	1·26	776482	4·78	223518	8
53	710364	3·52	933596	1·26	776769	4·78	223231	7
54	710575	3·52	933520	1·26	777055	4·78	222945	6
55	710786	3·51	933445	1·26	777342	4·78	222658	5
56	710997	3·51	933369	1·26	777628	4·77	222372	4
57	711208	3·51	933293	1·26	777915	4·77	222085	3
58	711419	3·51	933217	1·26	778201	4·77	221799	2
59	711629	3·50	933141	1·26	778487	4·77	221512	1
60	711839	3·50	933066	1·26	778774	4·77	221226	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

(59 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·711839	3·50	9·933066	1·26	9·778774	4·77	10·221226	60
1	712050	3·50	932990	1·27	779060	4·77	220940	59
2	712260	3·50	932914	1·27	779346	4·76	220654	58
3	712469	3·49	932838	1·27	779632	4·76	220368	57
4	712679	3·49	932762	1·27	779918	4·76	220082	56
5	712889	3·49	932685	1·27	780203	4·76	219797	55
6	713098	3·49	932609	1·27	780489	4·76	219511	54
7	713308	3·49	932533	1·27	780775	4·76	219225	53
8	713517	3·48	932457	1·27	781060	4·76	218940	52
9	713726	3·48	932380	1·27	781346	4·75	218654	51
10	713935	3·48	932304	1·27	781631	4·75	218369	50
11	9·714144	3·48	9·932228	1·27	9·781916	4·75	10·218084	49
12	714352	3·47	932151	1·27	782201	4·75	217799	48
13	714561	3·47	932075	1·28	782486	4·75	217514	47
14	714769	3·47	931998	1·28	782771	4·75	217229	46
15	714978	3·47	931921	1·28	783056	4·75	216944	45
16	715186	3·47	931845	1·28	783341	4·75	216659	44
17	715394	3·46	931768	1·28	783626	4·74	216374	43
18	715602	3·46	931691	1·28	783910	4·74	216090	42
19	715809	3·46	931614	1·28	784195	4·74	215805	41
20	716017	3·46	931537	1·28	784479	4·74	215521	40
21	9·716224	3·45	9·931460	1·28	9·784764	4·74	10·215236	39
22	716432	3·45	931383	1·28	785048	4·74	214952	38
23	716639	3·45	931306	1·28	785332	4·73	214668	37
24	716846	3·45	931229	1·29	785616	4·73	214384	36
25	717053	3·45	931152	1·29	785900	4·73	214100	35
26	717259	3·44	931075	1·29	786184	4·73	213816	34
27	717466	3·44	930998	1·29	786468	4·73	213532	33
28	717673	3·44	930921	1·29	786752	4·73	213248	32
29	717879	3·44	930843	1·29	787036	4·73	212964	31
30	718085	3·43	930766	1·29	787319	4·72	212681	30
31	9·718291	3·43	9·930688	1·29	9·787603	4·72	10·212397	29
32	718497	3·43	930611	1·29	787886	4·72	212114	28
33	718703	3·43	930533	1·29	788170	4·72	211830	27
34	718909	3·43	930456	1·29	788453	4·72	211547	26
35	719114	3·42	930378	1·29	788736	4·72	211264	25
36	719320	3·42	930300	1·30	789019	4·72	210981	24
37	719525	3·42	930223	1·30	789302	4·71	210698	23
38	719730	3·42	930145	1·30	789585	4·71	210415	22
39	719935	3·41	930067	1·30	789868	4·71	210132	21
40	720140	3·41	929989	1·30	790151	4·71	209849	20
41	9·720345	3·41	9·929911	1·30	9·790433	4·71	10·209567	19
42	720549	3·41	929833	1·30	790716	4·71	209284	18
43	720754	3·40	929755	1·30	790999	4·71	209001	17
44	720958	3·40	929677	1·30	791281	4·71	208719	16
45	721162	3·40	929599	1·30	791563	4·71	208437	15
46	721366	3·40	929521	1·30	791846	4·70	208154	14
47	721570	3·40	929442	1·30	792128	4·70	207872	13
48	721774	3·39	929364	1·31	792410	4·70	207590	12
49	721978	3·39	929286	1·31	792692	4·70	207308	11
50	722181	3·39	929207	1·31	792974	4·70	207026	10
51	9·722385	3·39	9·929129	1·31	9·793256	4·70	10·206744	9
52	722588	3·39	929050	1·31	793538	4·69	206462	8
53	722791	3·38	928972	1·31	793819	4·69	206181	7
54	722994	3·38	928893	1·31	794101	4·69	205899	6
55	723197	3·38	928815	1·31	794383	4·69	205617	5
56	723400	3·38	928736	1·31	794664	4·69	205336	4
57	723603	3·37	928657	1·31	794945	4·69	205055	3
58	723805	3·37	928578	1·31	795227	4·69	204773	2
59	724007	3·37	928499	1·31	795508	4·68	204492	1
60	724210	3·37	928420	1·31	795789	4·68	204211	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

(58 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·671609	3·96	9·945935	1·12	9·725674	5·08	10·274325	60
1	671847	3·95	945868	1·12	725979	5·08	274021	59
2	672084	3·95	945800	1·12	726284	5·07	273716	58
3	672321	3·95	945733	1·12	726588	5·07	273412	57
4	672558	3·95	945666	1·12	726892	5·07	273108	56
5	672795	3·94	945598	1·12	727197	5·07	272803	55
6	673032	3·94	945531	1·12	727501	5·07	272499	54
7	673268	3·94	945464	1·13	727805	5·06	272195	53
8	673505	3·94	945396	1·13	728109	5·06	271891	52
9	673741	3·93	945328	1·13	728412	5·06	271588	51
10	673977	3·93	945261	1·13	728716	5·06	271284	50
11	9·674213	3·93	9·945193	1·13	9·729020	5·06	10·270980	49
12	674448	3·92	945125	1·13	729323	5·05	270677	48
13	674684	3·92	945058	1·13	729626	5·05	270374	47
14	674919	3·92	944990	1·13	729929	5·05	270071	46
15	675155	3·92	944922	1·13	730233	5·05	269767	45
16	675390	3·91	944854	1·13	730535	5·05	269465	44
17	675624	3·91	944786	1·13	730838	5·04	269162	43
18	675859	3·91	944718	1·13	731141	5·04	268859	42
19	676094	3·91	944650	1·13	731444	5·04	268556	41
20	676328	3·90	944582	1·14	731746	5·04	268254	40
21	9·676562	3·90	9·944514	1·14	9·732048	5·04	10·267952	39
22	676796	3·90	944446	1·14	732351	5·03	267649	38
23	677030	3·90	944377	1·14	732653	5·03	267347	37
24	677264	3·89	944309	1·14	732955	5·03	267045	36
25	677498	3·89	944241	1·14	733257	5·03	266743	35
26	677731	3·89	944172	1·14	733558	5·03	266442	34
27	677964	3·88	944104	1·14	733860	5·02	266140	33
28	678197	3·88	944036	1·14	734162	5·02	265838	32
29	678430	3·88	943967	1·14	734463	5·02	265537	31
30	678663	3·88	943899	1·14	734764	5·02	265236	30
31	9·678895	3·87	9·943830	1·14	9·735066	5·02	10·264934	29
32	679128	3·87	943761	1·14	735367	5·02	264633	28
33	679360	3·87	943693	1·15	735668	5·01	264332	27
34	679592	3·87	943624	1·15	735969	5·01	264031	26
35	679824	3·86	943555	1·15	736269	5·01	263731	25
36	680056	3·86	943486	1·15	736570	5·01	263430	24
37	680288	3·86	943417	1·15	736871	5·01	263129	23
38	680519	3·85	943348	1·15	737171	5·00	262829	22
39	680750	3·85	943279	1·15	737471	5·00	262529	21
40	680982	3·85	943210	1·15	737771	5·00	262229	20
41	9·681213	3·85	9·943141	1·15	9·738071	5·00	10·261929	19
42	681443	3·84	943072	1·15	738371	5·00	261629	18
43	681674	3·84	943003	1·15	738671	4·99	261329	17
44	681905	3·84	942934	1·15	738971	4·99	261029	16
45	682135	3·84	942864	1·15	739271	4·99	260729	15
46	682365	3·83	942795	1·16	739570	4·99	260430	14
47	682595	3·83	942726	1·16	739870	4·99	260130	13
48	682825	3·83	942656	1·16	740169	4·99	259831	12
49	683055	3·83	942587	1·16	740468	4·98	259532	11
50	683284	3·82	942517	1·16	740767	4·98	259233	10
51	9·683514	3·82	9·942448	1·16	9·741066	4·98	10·258934	9
52	683743	3·82	942378	1·16	741365	4·98	258635	8
53	683972	3·82	942308	1·16	741664	4·98	258336	7
54	684201	3·81	942239	1·16	741962	4·97	258038	6
55	684430	3·81	942169	1·16	742261	4·97	257739	5
56	684658	3·81	942099	1·16	742559	4·97	257441	4
57	684887	3·80	942029	1·16	742858	4·97	257142	3
58	685115	3·80	941959	1·16	743156	4·97	256844	2
59	685343	3·80	941889	1·17	743454	4·97	256546	1
60	685571	3·80	941819	1·17	743752	4·96	256248	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9 685571	3·80	9·941819	1·17	9·743752	4·96	10·256248	60
1	685799	3·79	941749	1·17	744050	4·96	255950	59
2	686027	3·79	941679	1·17	744348	4·96	255652	58
3	686254	3·79	941609	1·17	744645	4·96	255355	57
4	686482	3·79	941539	1·17	744943	4·96	255057	56
5	686709	3·78	941469	1·17	745240	4·96	254760	55
6	686936	3·78	941398	1·17	745538	4·95	254462	54
7	687163	3·78	941328	1·17	745835	4·95	254165	53
8	687389	3·78	941258	1·17	746132	4·95	253868	52
9	687616	3·77	941187	1·17	746429	4·95	253571	51
10	687843	3·77	941117	1·17	746726	4·95	253274	50
11	9·688069	3·77	9·941046	1·18	9·747023	4·94	10 252977	49
12	688295	3·77	940975	1·18	747319	4·94	252681	48
13	688521	3·76	940905	1·18	747616	4·94	252384	47
14	688747	3·76	940834	1·18	747913	4·94	252087	46
15	688972	3·76	940763	1·18	748209	4·94	251791	45
16	689198	3·76	940693	1·18	748505	4·93	251495	44
17	689423	3·75	940622	1·18	748801	4·93	251199	43
18	689648	3·75	940551	1·18	749097	4·93	250903	42
19	689873	3·75	940480	1·18	749393	4·93	250607	41
20	690098	3·75	940409	1·18	749689	4·93	250311	40
21	9·690323	3·74	9·940338	1·18	9·749985	4·93	10·250015	39
22	690548	3·74	940267	1·18	750281	4·92	249719	38
23	690772	3·74	940196	1·18	750576	4·92	249424	37
24	690996	3·74	940125	1·19	750872	4·92	249128	36
25	691220	3·73	940054	1·19	751167	4·92	248833	35
26	691444	3·73	939982	1·19	751462	4·92	248538	34
27	691668	3·73	939911	1·19	751757	4·92	248243	33
28	691892	3·73	939840	1·19	752052	4·91	247948	32
29	692115	3·72	939768	1·19	752347	4·91	247653	31
30	692339	3·72	939697	1·19	752642	4·91	247358	30
31	9·692562	3·72	9·939625	1·19	9·752937	4·91	10·247063	29
32	692785	3·71	939554	1·19	753231	4·91	246769	28
33	693008	3·71	939482	1·19	753526	4·91	246474	27
34	693231	3·71	939410	1·19	753820	4·90	246180	26
35	693453	3·71	939339	1·19	754115	4·90	245885	25
36	693676	3·70	939267	1·20	754409	4·90	245591	24
37	693898	3·70	939195	1·20	754703	4·90	245297	23
38	694120	3·70	939123	1·20	754997	4·90	245003	22
39	694342	3·70	939052	1·20	755291	4·90	244709	21
40	694564	3·69	938980	1·20	755585	4·89	244415	20
41	9·694786	3·69	9·938908	1·20	9·755878	4·89	10·244122	19
42	695007	3·69	938836	1·20	756172	4·89	243828	18
43	695229	3·69	938763	1·20	756465	4·89	243535	17
44	695450	3·68	938691	1·20	756759	4·89	243241	16
45	695671	3·68	938619	1·20	757052	4·89	242948	15
46	695892	3·68	938547	1·20	757345	4·88	242655	14
47	696113	3·68	938475	1·20	757638	4·88	242362	13
48	690334	3·67	938402	1·21	757931	4·88	242069	12
49	690554	3·67	938330	1·21	758224	4·88	241776	11
50	690775	3·67	938258	1·21	758517	4·88	241483	10
51	9·696995	3·67	9·938185	1·21	9·758810	4·88	10·241190	9
52	697215	3·66	938113	1·21	759102	4·87	240898	8
53	697435	3·66	938040	1·21	759395	4·87	240605	7
54	697654	3·66	937967	1·21	759687	4·87	240313	6
55	697874	3·66	937895	1·21	759979	4·87	240021	5
56	698094	3·65	937822	1·21	760272	4·87	239728	4
57	698313	3·65	937749	1·21	760564	4·87	239436	3
58	698532	3·65	937676	1·21	760856	4·86	239144	2
59	698751	3·65	937604	1·21	761148	4·86	238852	1
60	698970	3·64	937531	1·21	761439	4·86	238561	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

27 (60 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·698970	3·64	9·937531	1·21	9·761439	4·86	10·238561	60
1	699189	3·64	937458	1·22	761731	4·86	238269	59
2	699407	3·64	937385	1·22	762023	4·86	237977	58
3	699626	3·64	937312	1·22	762314	4·86	237686	57
4	699844	3·63	937238	1·22	762606	4·85	237394	56
5	700062	3·63	937165	1·22	762897	4·85	237103	55
6	700280	3·63	937092	1·22	763188	4·85	236812	54
7	700498	3·63	937019	1·22	763479	4·85	236521	53
8	700716	3·63	936946	1·22	763770	4·85	236230	52
9	700933	3·62	936872	1·22	764061	4·85	235939	51
10	701151	3·62	936799	1·22	764352	4·84	235648	50
11	9·701368	3·62	9·936725	1·22	9·764643	4·84	10·235357	49
12	701585	3·62	936652	1·23	764933	4·84	235067	48
13	701802	3·61	936578	1·23	765224	4·84	234776	47
14	702019	3·61	936505	1·23	765514	4·84	234486	46
15	702236	3·61	936431	1·23	765805	4·84	234195	45
16	702452	3·61	936357	1·23	766095	4·84	233905	44
17	702669	3·60	936284	1·23	766385	4·83	233615	43
18	702885	3·60	936210	1·23	766675	4·83	233325	42
19	703101	3·60	936136	1·23	766965	4·83	233035	41
20	703317	3·60	936062	1·23	767255	4·83	232745	40
21	9·703533	3·59	9·935988	1·23	9·767545	4·83	10·232455	39
22	703749	3·59	935914	1·23	767834	4·83	232166	38
23	703964	3·59	935840	1·23	768124	4·82	231876	37
24	704179	3·59	935766	1·24	768413	4·82	231587	36
25	704395	3·59	935692	1·24	768703	4·82	231297	35
26	704610	3·58	935618	1·24	768992	4·82	231008	34
27	704825	3·58	935543	1·24	769281	4·82	230719	33
28	705040	3·58	935469	1·24	769570	4·82	230430	32
29	705254	3·58	935395	1·24	769860	4·81	230140	31
30	705469	3·57	935320	1·24	770148	4·81	229852	30
31	9·705683	3·57	9·935246	1·24	9·770437	4·81	10·229563	29
32	705898	3·57	935171	1·24	770726	4·81	229274	28
33	706112	3·57	935097	1·24	771015	4·81	228985	27
34	706326	3·56	935022	1·24	771303	4·81	228697	26
35	706539	3·56	934948	1·24	771592	4·81	228408	25
36	706753	3·56	934873	1·24	771880	4·80	228120	24
37	706967	3·56	934798	1·25	772168	4·80	227832	23
38	707180	3·55	934723	1·25	772457	4·80	227543	22
39	707393	3·55	934649	1·25	772745	4·80	227255	21
40	707606	3·55	934574	1·25	773033	4·80	226967	20
41	9·707819	3·55	9·934499	1·25	9·773321	4·80	10·226679	19
42	708032	3·54	934424	1·25	773608	4·79	226392	18
43	708245	3·54	934349	1·25	773896	4·79	226104	17
44	708458	3·54	934274	1·25	774184	4·79	225816	16
45	708670	3·54	934199	1·25	774471	4·79	225529	15
46	708882	3·53	934123	1·25	774759	4·79	225241	14
47	709094	3·53	934048	1·25	775046	4·79	224954	13
48	709306	3·53	933973	1·25	775333	4·79	224667	12
49	709518	3·53	933898	1·26	775621	4·78	224379	11
50	709730	3·53	933822	1·26	775908	4·78	224092	10
51	9·709941	3·52	9·933747	1·26	9·776195	4·78	10·223805	9
52	710153	3·52	933671	1·26	776482	4·78	223518	8
53	710364	3·52	933596	1·26	776769	4·78	223231	7
54	710575	3·52	933520	1·26	777055	4·78	222945	6
55	710786	3·51	933445	1·26	777342	4·78	222658	5
56	710997	3·51	933369	1·26	777628	4·77	222372	4
57	711208	3·51	933293	1·26	777915	4·77	222085	3
58	711419	3·51	933217	1·26	778201	4·77	221799	2
59	711629	3·50	933141	1·26	778487	4·77	221512	1
60	711839	3·50	933066	1·26	778774	4·77	221226	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

(59 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·711839	3·50	9·933066	1·26	9·778774	4·77	10·221226	60
1	712050	3·50	932990	1·27	779060	4·77	220940	59
2	712260	3·50	932914	1·27	779346	4·76	220654	58
3	712469	3·49	932838	1·27	779632	4·76	220368	57
4	712679	3·49	932762	1·27	779918	4·76	220082	56
5	712889	3·49	932685	1·27	780203	4·76	219797	55
6	713098	3·49	932609	1·27	780489	4·76	219511	54
7	713308	3·49	932533	1·27	780775	4·76	219225	53
8	713517	3·48	932457	1·27	781060	4·76	218940	52
9	713726	3·48	932380	1·27	781346	4·75	218654	51
10	713935	3·48	932304	1·27	781631	4·75	218369	50
11	9·714144	3·48	9·932228	1·27	9·781916	4·75	10·218084	49
12	714352	3·47	932151	1·27	782201	4·75	217799	48
13	714561	3·47	932075	1·28	782486	4·75	217514	47
14	714769	3·47	931998	1·28	782771	4·75	217229	46
15	714978	3·47	931921	1·28	783056	4·75	216944	45
16	715186	3·47	931845	1·28	783341	4·75	216659	44
17	715394	3·46	931768	1·28	783626	4·74	216374	43
18	715602	3·46	931691	1·28	783910	4·74	216090	42
19	715809	3·46	931614	1·28	784195	4·74	215805	41
20	716017	3·46	931537	1·28	784479	4·74	215521	40
21	9·716224	3·45	9·931460	1·28	9·784764	4·74	10·215236	39
22	716432	3·45	931383	1·28	785048	4·74	214952	38
23	716639	3·45	931306	1·28	785332	4·73	214668	37
24	716846	3·45	931229	1·29	785616	4·73	214384	36
25	717053	3·45	931152	1·29	785900	4·73	214100	35
26	717259	3·44	931075	1·29	786184	4·73	213816	34
27	717466	3·44	930998	1·29	786468	4·73	213532	33
28	717673	3·44	930921	1·29	786752	4·73	213248	32
29	717879	3·44	930843	1·29	787036	4·73	212964	31
30	718085	3·43	930766	1·29	787319	4·72	212681	30
31	9·718291	3·43	9·930688	1·29	9·787603	4·72	10·212397	29
32	718497	3·43	930611	1·29	787886	4·72	212114	28
33	718703	3·43	930533	1·29	788170	4·72	211830	27
34	718909	3·43	930456	1·29	788453	4·72	211547	26
35	719114	3·42	930378	1·29	788736	4·72	211264	25
36	719320	3·42	930300	1·30	789019	4·72	210981	24
37	719525	3·42	930223	1·30	789302	4·71	210698	23
38	719730	3·42	930145	1·30	789585	4·71	210415	22
39	719935	3·41	930067	1·30	789868	4·71	210132	21
40	720140	3·41	929989	1·30	790151	4·71	209849	20
41	9·720345	3·41	9·929911	1·30	9·790433	4·71	10·209567	19
42	720549	3·41	929833	1·30	790716	4·71	209284	18
43	720754	3·40	929755	1·30	790999	4·71	209001	17
44	720958	3·40	929677	1·30	791281	4·71	208719	16
45	721162	3·40	929599	1·30	791563	4·70	208437	15
46	721366	3·40	929521	1·30	791846	4·70	208154	14
47	721570	3·40	929442	1·30	792128	4·70	207872	13
48	721774	3·39	929364	1·31	792410	4·70	207590	12
49	721978	3·39	929286	1·31	792692	4·70	207308	11
50	722181	3·39	929207	1·31	792974	4·70	207026	10
51	9·722385	3·39	9·929129	1·31	9·793256	4·70	10·206744	9
52	722588	3·39	929050	1·31	793538	4·69	206462	8
53	722791	3·38	928972	1·31	793819	4·69	206181	7
54	722994	3·38	928893	1·31	794101	4·69	205899	6
55	723197	3·38	928815	1·31	794383	4·69	205617	5
56	723400	3·38	928736	1·31	794664	4·69	205336	4
57	723603	3·37	928657	1·31	794945	4·69	205055	3
58	723805	3·37	928578	1·31	795227	4·69	204773	2
59	724007	3·37	928499	1·31	795508	4·68	204492	1
60	724210	3·37	928420	1·31	795789	4·68	204211	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

(58 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·724210	3·37	9·928420	1·32	9·795789	4·68	10·204211	60
1	724412	3·37	928342	1·32	796070	4·68	203930	59
2	724614	3·36	928263	1·32	796351	4·68	203649	58
3	724816	3·36	928183	1·32	796632	4·68	203368	57
4	725017	3·36	928104	1·32	796913	4·68	203087	56
5	725219	3·36	928025	1·32	797194	4·68	202806	55
6	725420	3·35	927946	1·32	797475	4·68	202525	54
7	725622	3·35	927867	1·32	797755	4·68	202245	53
8	725823	3·35	927787	1·32	798036	4·67	201964	52
9	726024	3·35	927708	1·32	798316	4·67	201684	51
10	726225	3·35	927629	1·32	798596	4·67	201404	50
11	9·726426	3·34	9·927549	1·32	9·798877	4·67	10·201123	49
12	726626	3·34	927470	1·33	799157	4·67	200843	48
13	726827	3·34	927390	1·33	799437	4·67	200563	47
14	727027	3·34	927310	1·33	799717	4·67	200283	46
15	727228	3·34	927231	1·33	799997	4·66	200003	45
16	727428	3·33	927151	1·33	800277	4·66	199723	44
17	727628	3·33	927071	1·33	800557	4·66	199443	43
18	727828	3·33	926991	1·33	800836	4·66	199164	42
19	728027	3·33	926911	1·33	801116	4·66	198884	41
20	728227	3·33	926831	1·33	801396	4·66	198604	40
21	9·728427	3·32	9·926751	1·33	9·801675	4·66	10·198325	39
22	728626	3·32	926071	1·33	801955	4·66	198045	38
23	728825	3·32	926591	1·33	802234	4·65	197766	37
24	729024	3·32	926511	1·34	802513	4·65	197487	36
25	729223	3·31	926431	1·34	802792	4·65	197208	35
26	729422	3·31	926351	1·34	803072	4·65	196928	34
27	729621	3·31	926270	1·34	803351	4·65	196649	33
28	729820	3·31	926190	1·34	803630	4·65	196370	32
29	730018	3·30	926110	1·34	803908	4·65	196092	31
30	730216	3·30	926029	1·34	804187	4·65	195813	30
31	9·730415	3·30	9·925949	1·34	9·804466	4·64	10·195534	29
32	730613	3·30	925868	1·34	804745	4·64	195255	28
33	730811	3·30	925788	1·34	805023	4·64	194977	27
34	731009	3·29	925707	1·34	805302	4·64	194698	26
35	731206	3·29	925626	1·34	805580	4·64	194420	25
36	731404	3·29	925545	1·35	805859	4·64	194141	24
37	731602	3·29	925465	1·35	806137	4·64	193863	23
38	731799	3·29	925384	1·35	806415	4·63	193585	22
39	731996	3·28	925303	1·35	806693	4·63	193307	21
40	732193	3·28	925222	1·35	806971	4·63	193029	20
41	9·732390	3·28	9·925141	1·35	9·807249	4·63	10·192751	19
42	732587	3·28	925060	1·35	807527	4·63	192473	18
43	732784	3·28	924979	1·35	807805	4·63	192195	17
44	732980	3·27	924897	1·35	808083	4·63	191917	16
45	733177	3·27	924816	1·35	808361	4·63	191639	15
46	733373	3·27	924735	1·36	808638	4·62	191362	14
47	733569	3·27	924654	1·36	808916	4·62	191084	13
48	733765	3·27	924572	1·36	809193	4·62	190807	12
49	733961	3·26	924491	1·36	809471	4·62	190529	11
50	734157	3·26	924409	1·36	809748	4·62	190252	10
51	9·734353	3·26	9·924328	1·36	9·810025	4·62	10·189975	9
52	734549	3·26	924246	1·36	810302	4·62	189698	8
53	734744	3·25	924164	1·36	810580	4·62	189420	7
54	734939	3·25	924083	1·36	810857	4·62	189143	6
55	735135	3·25	924001	1·36	811134	4·61	188866	5
56	735330	3·25	923919	1·36	811410	4·61	188590	4
57	735525	3·25	923837	1·36	811687	4·61	188313	3
58	735719	3·24	923755	1·37	811964	4·61	188036	2
59	735914	3·24	923673	1·37	812241	4·61	187759	1
60	736109	3·24	923591	1·37	812517	4·61	187483	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

(57 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·779463	2·79	9·902349	1·59	9·877114	4·38	10·122886	60
1	779631	2·79	902253	1·59	877377	4·38	122623	59
2	779798	2·79	902158	1·59	877640	4·38	122360	58
3	779966	2·79	902063	1·59	877903	4·38	122097	57
4	780133	2·79	901967	1·59	878165	4·38	121835	56
5	780300	2·78	901872	1·59	878428	4·38	121572	55
6	780467	2·78	901776	1·59	878691	4·38	121309	54
7	780634	2·78	901681	1·59	878953	4·37	121047	53
8	780801	2·78	901585	1·59	879216	4·37	120784	52
9	780968	2·78	901490	1·59	879478	4·37	120522	51
10	781134	2·78	901394	1·60	879741	4·37	120259	50
11	9·781301	2·77	9·901298	1·60	9·880003	4·37	10·119997	49
12	781468	2·77	901202	1·60	880265	4·37	119735	48
13	781634	2·77	901106	1·60	880528	4·37	119472	47
14	781800	2·77	901010	1·60	880790	4·37	119210	46
15	781966	2·77	900914	1·60	881052	4·37	118948	45
16	782132	2·77	900818	1·60	881314	4·37	118686	44
17	782298	2·76	900722	1·60	881576	4·37	118424	43
18	782464	2·76	900626	1·60	881839	4·37	118161	42
19	782630	2·76	900529	1·60	882101	4·37	117899	41
20	782796	2·76	900433	1·61	882363	4·36	117637	40
21	9·782961	2·76	9·900337	1·61	9·882625	4·36	10·117375	39
22	783127	2·76	900240	1·61	882887	4·36	117113	38
23	783292	2·75	900144	1·61	883148	4·36	116852	37
24	783458	2·75	900047	1·61	883410	4·36	116590	36
25	783623	2·75	899951	1·61	883672	4·36	116328	35
26	783788	2·75	899854	1·61	883934	4·36	116066	34
27	783953	2·75	899757	1·61	884196	4·36	115804	33
28	784118	2·75	899660	1·61	884457	4·36	115543	32
29	784282	2·74	899564	1·61	884719	4·36	115281	31
30	784447	2·74	899467	1·62	884980	4·36	115020	30
31	9·784612	2·74	9·899370	1·62	9·885242	4·36	10·114758	29
32	784776	2·74	899273	1·62	885503	4·36	114497	28
33	784941	2·74	899176	1·62	885765	4·36	114235	27
34	785105	2·74	899078	1·62	886026	4·36	113974	26
35	785269	2·73	898981	1·62	886288	4·36	113712	25
36	785433	2·73	898884	1·62	886549	4·35	113451	24
37	785597	2·73	898787	1·62	886810	4·35	113190	23
38	785761	2·73	898689	1·62	887072	4·35	112928	22
39	785925	2·73	898592	1·62	887333	4·35	112667	21
40	786089	2·73	898494	1·63	887594	4·35	112406	20
41	9·786252	2·72	9·898397	1·63	9·887855	4·35	10·112145	19
42	786416	2·72	898299	1·63	888116	4·35	111884	18
43	786579	2·72	898202	1·63	888377	4·35	111623	17
44	786742	2·72	898104	1·63	888639	4·35	111361	16
45	786906	2·72	898006	1·63	888900	4·35	111100	15
46	787069	2·72	897908	1·63	889160	4·35	110840	14
47	787232	2·71	897810	1·63	889421	4·35	110579	13
48	787395	2·71	897712	1·63	889682	4·35	110318	12
49	787557	2·71	897614	1·63	889943	4·35	110057	11
50	787720	2·71	897516	1·63	890204	4·34	·09796	10
51	9·787883	2·71	9·897418	1·64	9·890465	4·34	10·109535	9
52	788045	2·71	897320	1·64	890725	4·34	109275	8
53	788208	2·71	897222	1·64	890986	4·34	109014	7
54	788370	2·70	897123	1·64	891247	4·34	108753	6
55	788532	2·70	897025	1·64	891507	4·34	108493	5
56	788694	2·70	896926	1·64	891768	4·34	108232	4
57	788856	2·70	896828	1·64	892028	4·34	107972	3
58	789018	2·70	896729	1·64	892289	4·34	107711	2
59	789180	2·70	896631	1·64	892549	4·34	107451	1
60	789342	2·69	896532	1·64	892810	4·34	107190	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

(52 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·747562	3·12	9·918574	1·42	9·828987	4·54	10·171013	60
1	747749	3·12	918489	1·42	829260	4·54	170740	59
2	747936	3·12	918404	1·42	829532	4·54	170468	58
3	748123	3·11	918318	1·42	829805	4·54	170195	57
4	748310	3·11	918233	1·42	830077	4·54	169923	56
5	748497	3·11	918147	1·42	830349	4·53	169651	55
6	748683	3·11	918062	1·42	830621	4·53	169379	54
7	748870	3·11	917976	1·43	830893	4·53	169107	53
8	749056	3·10	917891	1·43	831165	4·53	168835	52
9	749243	3·10	917805	1·43	831437	4·53	168563	51
10	749429	3·10	917719	1·43	831709	4·53	168291	50
11	9·749615	3·10	9·917634	1·43	9·831981	4·53	10·168019	49
12	749801	3·10	917548	1·43	832253	4·53	167747	48
13	749987	3·09	917462	1·43	832525	4·53	167475	47
14	750172	3·09	917376	1·43	832796	4·53	167204	46
15	750358	3·09	917290	1·43	833068	4·52	166932	45
16	750543	3·09	917204	1·43	833339	4·52	166661	44
17	750729	3·09	917118	1·44	833611	4·52	166389	43
18	750914	3·08	917032	1·44	833882	4·52	166118	42
19	751099	3·08	916946	1·44	834154	4·52	165846	41
20	751284	3·08	916859	1·44	834425	4·52	165575	40
21	9·751469	3·08	9·916773	1·44	9·834696	4·52	10·165304	39
22	751654	3·08	916687	1·44	834967	4·52	165033	38
23	751839	3·08	916600	1·44	835238	4·52	164762	37
24	752023	3·07	916514	1·44	835509	4·52	164491	36
25	752208	3·07	916427	1·44	835780	4·51	164220	35
26	752392	3·07	916341	1·44	836051	4·51	163949	34
27	752576	3·07	916254	1·44	836322	4·51	163678	33
28	752760	3·07	916167	1·45	836593	4·51	163407	32
29	752944	3·06	916081	1·45	836864	4·51	163136	31
30	753128	3·06	915994	1·45	837134	4·51	162866	30
31	9·753312	3·06	9·915907	1·45	9·837405	4·51	10·162595	29
32	753495	3·06	915820	1·45	837675	4·51	162325	28
33	753679	3·06	915733	1·45	837946	4·51	162054	27
34	753862	3·05	915646	1·45	838216	4·51	161784	26
35	754046	3·05	915559	1·45	838487	4·50	161513	25
36	754229	3·05	915472	1·45	838757	4·50	161243	24
37	754412	3·05	915385	1·45	839027	4·50	160973	23
38	754595	3·05	915297	1·45	839297	4·50	160703	22
39	754778	3·04	915210	1·45	839568	4·50	160432	21
40	754960	3·04	915123	1·46	839838	4·50	160162	20
41	9·755143	3·04	9·915035	1·46	9·840108	4·50	10·159892	19
42	755326	3·04	914948	1·46	840378	4·50	159622	18
43	755508	3·04	914860	1·46	840647	4·50	159353	17
44	755690	3·04	914773	1·46	840917	4·49	159083	16
45	755872	3·03	914685	1·46	841187	4·49	158813	15
46	756054	3·03	914598	1·46	841457	4·49	158543	14
47	756236	3·03	914510	1·46	841726	4·49	158274	13
48	756418	3·03	914422	1·46	841996	4·49	158004	12
49	756600	3·03	914334	1·46	842266	4·49	157734	11
50	756782	3·02	914246	1·47	842535	4·49	157465	10
51	9·756963	3·02	9·914158	1·47	9·842805	4·49	10·157195	9
52	757144	3·02	914070	1·47	843074	4·49	156926	8
53	757326	3·02	913982	1·47	843343	4·49	156657	7
54	757507	3·02	913894	1·47	843612	4·49	156388	6
55	757688	3·01	913806	1·47	843882	4·48	156118	5
56	757869	3·01	913718	1·47	844151	4·48	155849	4
57	758050	3·01	913630	1·47	844420	4·48	155580	3
58	758230	3·01	913541	1·47	844689	4·48	155311	2
59	758411	3·01	913453	1·47	844958	4·48	155042	1
60	758591	3·01	913365	1·47	845227	4·48	154773	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·758591	3·01	9·913365	1·47	9·845227	4·48	10·154773	60
1	758772	3·00	913276	1·47	845496	4·48	154504	59
2	758952	3·00	913187	1·48	845764	4·48	154236	58
3	759132	3·00	913099	1·48	846033	4·48	153967	57
4	759312	3·00	913010	1·48	846302	4·48	153698	56
5	759492	3·00	912922	1·48	846570	4·47	153430	55
6	759672	2·99	912833	1·48	846839	4·47	153161	54
7	759852	2·99	912744	1·48	847107	4·47	152893	53
8	760031	2·99	912655	1·48	847376	4·47	152624	52
9	760211	2·99	912566	1·48	847644	4·47	152356	51
10	760390	2·99	912477	1·48	847913	4·47	152087	50
11	9·760569	2·98	9·912388	1·48	9·848181	4·47	10·151819	49
12	760748	2·98	912299	1·49	848449	4·47	151551	48
13	760927	2·98	912210	1·49	848717	4·47	151283	47
14	761106	2·98	912121	1·49	848986	4·47	151014	46
15	761285	2·98	912031	1·49	849254	4·47	150746	45
16	761464	2·98	911942	1·49	849522	4·47	150478	44
17	761642	2·97	911853	1·49	849790	4·46	150210	43
18	761821	2·97	911763	1·49	850058	4·46	149942	42
19	761999	2·97	911674	1·49	850325	4·46	149675	41
20	762177	2·97	911584	1·49	850593	4·46	149407	40
21	9·762356	2·97	9·911495	1·49	9·850861	4·46	10·149139	39
22	762534	2·96	911405	1·49	851129	4·46	148871	38
23	762712	2·96	911315	1·50	851396	4·46	148604	37
24	762889	2·96	911226	1·50	851664	4·46	148336	36
25	763067	2·96	911136	1·50	851931	4·46	148069	35
26	763245	2·96	911046	1·50	852199	4·46	147801	34
27	763422	2·96	910956	1·50	852466	4·46	147534	33
28	763600	2·95	910866	1·50	852733	4·45	147267	32
29	763777	2·95	910776	1·50	853001	4·45	146999	31
30	763954	2·95	910686	1·50	853268	4·45	146732	30
31	9·764131	2·95	9·910596	1·50	9·853535	4·45	10·146465	29
32	764308	2·95	910506	1·50	853802	4·45	146198	28
33	764485	2·94	910415	1·50	854069	4·45	145931	27
34	764662	2·94	910325	1·51	854336	4·45	145664	26
35	764838	2·94	910235	1·51	854603	4·45	145397	25
36	765015	2·94	910144	1·51	854870	4·45	145130	24
37	765191	2·94	910054	1·51	855137	4·45	144863	23
38	765367	2·94	909963	1·51	855404	4·45	144596	22
39	765544	2·93	909873	1·51	855671	4·44	144329	21
40	765720	2·93	909782	1·51	855938	4·44	144062	20
41	9·765896	2·93	9·909691	1·51	9·856204	4·44	10·143796	19
42	766072	2·93	909601	1·51	856471	4·44	143529	18
43	766247	2·93	909510	1·51	856737	4·44	143263	17
44	766423	2·93	909419	1·51	857004	4·44	142996	16
45	766598	2·92	909328	1·52	857270	4·44	142730	15
46	766774	2·92	909237	1·52	857537	4·44	142463	14
47	766949	2·92	909146	1·52	857803	4·44	142197	13
48	767124	2·92	909055	1·52	858069	4·44	141931	12
49	767300	2·92	908964	1·52	858336	4·44	141664	11
50	767475	2·91	908873	1·52	858602	4·43	141398	10
51	9·767649	2·91	9·908781	1·52	9·858868	4·43	10·141132	9
52	767824	2·91	908690	1·52	859134	4·43	140866	8
53	767999	2·91	908599	1·52	859400	4·43	140600	7
54	768173	2·91	908507	1·52	859666	4·43	140334	6
55	768348	2·90	908416	1·53	859932	4·43	140068	5
56	768522	2·90	908324	1·53	860198	4·43	139802	4
57	768697	2·90	908233	1·53	860464	4·43	139536	3
58	768871	2·90	908141	1·53	860730	4·43	139270	2
59	769045	2·90	908049	1·53	860995	4·43	139005	1
60	769219	2·90	907958	1·53	861261	4·43	138739	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

(54 DEGREES.)

M.	Sine	D	Cosine	D.	Tang.	D.	Cotang.	
0	9·769219	2·90	9·907958	1·53	9·861261	4·43	10·138739	60
1	769393	2·89	907866	1·53	861527	4·43	138473	59
2	769566	2·89	907774	1·53	861792	4·42	138208	58
3	769740	2·89	907682	1·53	862058	4·42	137942	57
4	769913	2·89	907590	1·53	862323	4·42	137677	56
5	770087	2·89	907498	1·53	862589	4·42	137411	55
6	770260	2·88	907406	1·53	862854	4·42	137146	54
7	770433	2·88	907314	1·54	863119	4·42	136881	53
8	770606	2·88	907222	1·54	863385	4·42	136615	52
9	770779	2·88	907129	1·54	863650	4·42	136350	51
10	770952	2·88	907037	1·54	863915	4·42	136085	50
11	9·771125	2·88	9·906945	1·54	9·864180	4·42	10·135820	49
12	771298	2·87	906852	1·54	864445	4·42	135555	48
13	771470	2·87	906760	1·54	864710	4·42	135290	47
14	771643	2·87	906667	1·54	864975	4·41	135025	46
15	771815	2·87	906575	1·54	865240	4·41	134760	45
16	771987	2·87	906482	1·54	865505	4·41	134495	44
17	772159	2·87	906389	1·55	865770	4·41	134230	43
18	772331	2·86	906296	1·55	866035	4·41	133965	42
19	772503	2·86	906204	1·55	866300	4·41	133700	41
20	772675	2·86	906111	1·55	866564	4·41	133436	40
21	9·772847	2·86	9·906018	1·55	9·866829	4·41	10·133171	39
22	773018	2·86	905925	1·55	867094	4·41	132906	38
23	773190	2·86	905832	1·55	867358	4·41	132642	37
24	773361	2·85	905739	1·55	867623	4·41	132377	36
25	773533	2·85	905645	1·55	867887	4·41	132113	35
26	773704	2·85	905552	1·55	868152	4·40	131848	34
27	773875	2·85	905459	1·55	868416	4·40	131584	33
28	774046	2·85	905366	1·56	868680	4·40	131320	32
29	774217	2·85	905272	1·56	868945	4·40	131055	31
30	774388	2·84	905179	1·56	869209	4·40	130794	30
31	9·774558	2·84	9·905085	1·56	9·869473	4·40	10·130527	29
32	774729	2·84	904992	1·56	869737	4·40	130263	28
33	774899	2·84	904898	1·56	870001	4·40	129999	27
34	775070	2·84	904804	1·56	870265	4·40	129735	26
35	775240	2·84	904711	1·56	870529	4·40	129471	25
36	775410	2·83	904617	1·56	870793	4·40	129207	24
37	775580	2·83	904523	1·56	871057	4·40	128943	23
38	775750	2·83	904429	1·57	871321	4·40	128679	22
39	775920	2·83	904335	1·57	871585	4·40	128415	21
40	776090	2·83	904241	1·57	871849	4·39	128151	20
41	9·776259	2·83	9·904147	1·57	9·872112	4·39	10·127888	19
42	776429	2·82	904053	1·57	872376	4·39	127624	18
43	776598	2·82	903959	1·57	872640	4·39	127360	17
44	776768	2·82	903864	1·57	872903	4·39	127097	16
45	776937	2·82	903770	1·57	873167	4·39	126833	15
46	777106	2·82	903676	1·57	873430	4·39	126570	14
47	777275	2·81	903581	1·57	873694	4·39	126306	13
48	777444	2·81	903487	1·57	873957	4·39	126043	12
49	777613	2·81	903392	1·58	874220	4·39	125780	11
50	777781	2·81	903298	1·58	874484	4·39	125516	10
51	9·777950	2·81	9·903203	1·58	9·874747	4·39	10·125253	9
52	778119	2·81	903108	1·58	875010	4·39	124990	8
53	778287	2·80	903014	1·58	875273	4·38	124727	7
54	778455	2·80	902919	1·58	875536	4·38	124464	6
55	778624	2·80	902824	1·58	875800	4·38	124200	5
56	778792	2·80	902729	1·58	876063	4·38	123937	4
57	778960	2·80	902634	1·58	876326	4·38	123674	3
58	779128	2·80	902539	1·59	876589	4·38	123411	2
59	779295	2·79	902444	1·59	876851	4·38	123149	1
60	779463	2·79	902349	1·59	877114	4·38	122886	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang	M.

(53 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·779463	2·79	9·902349	1·59	9·877114	4·38	10·122886	60
1	779631	2·79	902253	1·59	877377	4·38	122623	59
2	779798	2·79	902158	1·59	877640	4·38	122360	58
3	779966	2·79	902063	1·59	877903	4·38	122097	57
4	780133	2·79	901967	1·59	878165	4·38	121835	56
5	780300	2·78	901872	1·59	878428	4·38	121572	55
6	780467	2·78	901776	1·59	878691	4·38	121309	54
7	780634	2·78	901681	1·59	878953	4·37	121047	53
8	780801	2·78	901585	1·59	879216	4·37	120784	52
9	780968	2·78	901490	1·59	879478	4·37	120522	51
10	781134	2·78	901394	1·60	879741	4·37	120259	50
11	9·781301	2·77	9·901298	1·60	9·880003	4·37	10·119997	49
12	781468	2·77	901202	1·60	880265	4·37	119735	48
13	781634	2·77	901106	1·60	880528	4·37	119472	47
14	781800	2·77	901010	1·60	880790	4·37	119210	46
15	781966	2·77	900914	1·60	881052	4·37	118948	45
16	782132	2·77	900818	1·60	881314	4·37	118686	44
17	782298	2·76	900722	1·60	881576	4·37	118424	43
18	782464	2·76	900626	1·60	881839	4·37	118161	42
19	782630	2·76	900529	1·60	882101	4·37	117899	41
20	782796	2·76	900433	1·61	882363	4·36	117637	40
21	9·782961	2·76	9·900337	1·61	9·882625	4·36	10·117375	39
22	783127	2·76	900240	1·61	882887	4·36	117113	38
23	783292	2·75	900144	1·61	883148	4·36	116852	37
24	783458	2·75	900047	1·61	883410	4·36	116590	36
25	783623	2·75	899951	1·61	883672	4·36	116328	35
26	783788	2·75	899854	1·61	883934	4·36	116066	34
27	783953	2·75	899757	1·61	884196	4·36	115804	33
28	784118	2·75	899660	1·61	884457	4·36	115543	32
29	784282	2·74	899564	1·61	884719	4·36	115281	31
30	784447	2·74	899467	1·62	884980	4·36	115020	30
31	9·784612	2·74	9·899370	1·62	9·885242	4·36	10·114758	29
32	784776	2·74	899273	1·62	885503	4·36	114497	28
33	784941	2·74	899176	1·62	885765	4·36	114235	27
34	785105	2·74	899078	1·62	886026	4·36	113974	26
35	785269	2·73	898981	1·62	886288	4·36	113712	25
36	785433	2·73	898884	1·62	886549	4·35	113451	24
37	785597	2·73	898787	1·62	886810	4·35	113190	23
38	785761	2·73	898689	1·62	887072	4·35	112928	22
39	785925	2·73	898592	1·62	887333	4·35	112667	21
40	786089	2·73	898494	1·63	887594	4·35	112406	20
41	9·786252	2·72	9·898397	1·63	9·887855	4·35	10·112145	19
42	786416	2·72	898299	1·63	888116	4·35	111884	18
43	786579	2·72	898202	1·63	888377	4·35	111623	17
44	786742	2·72	898104	1·63	888639	4·35	111361	16
45	786906	2·72	898006	1·63	888900	4·35	111100	15
46	787069	2·72	897908	1·63	889160	4·35	110840	14
47	787232	2·71	897810	1·63	889421	4·35	110579	13
48	787395	2·71	897712	1·63	889682	4·35	110318	12
49	787557	2·71	897614	1·63	889943	4·35	110057	11
50	787720	2·71	897516	1·63	890204	4·34	·09796	10
51	9·787883	2·71	9·897418	1·64	9·890465	4·34	10·109535	9
52	788045	2·71	897320	1·64	890725	4·34	109275	8
53	788208	2·71	897222	1·64	890986	4·34	109014	7
54	788370	2·70	897123	1·64	891247	4·34	108753	6
55	788532	2·70	897025	1·64	891507	4·34	108493	5
56	788694	2·70	896926	1·64	891768	4·34	108232	4
57	788856	2·70	896828	1·64	892028	4·34	107972	3
58	789018	2·70	896729	1·64	892289	4·34	107711	2
59	789180	2·70	896631	1·64	892549	4·34	107451	1
60	789342	2·69	896532	1·64	892810	4·34	107190	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

(52 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·789342	2·69	9·896532	1·64	9·892810	4·34	10·107190	60
1	789504	2·69	896433	1·65	893070	4·34	106930	59
2	789665	2·69	896335	1·65	893331	4·34	106669	58
3	789827	2·69	896236	1·65	893591	4·34	106409	57
4	789988	2·69	896137	1·65	893851	4·34	106149	56
5	790149	2·69	896038	1·65	894111	4·34	105889	55
6	790310	2·68	895939	1·65	894371	4·34	105629	54
7	790471	2·68	895840	1·65	894632	4·33	105368	53
8	790632	2·68	895741	1·65	894892	4·33	105108	52
9	790793	2·68	895641	1·65	895152	4·33	104848	51
10	790954	2·68	895542	1·65	895412	4·33	104588	50
11	9·791115	2·68	9·895443	1·66	9·895672	4·33	10·104328	49
12	791275	2·67	895343	1·66	895932	4·33	104068	48
13	791436	2·67	895244	1·66	896192	4·33	103808	47
14	791596	2·67	895145	1·66	896452	4·33	103548	46
15	791757	2·67	895045	1·66	896712	4·33	103288	45
16	791917	2·67	894945	1·66	896971	4·33	103029	44
17	792077	2·67	894846	1·66	897231	4·33	102769	43
18	792237	2·66	894746	1·66	897491	4·33	102509	42
19	792397	2·66	894646	1·66	897751	4·33	102249	41
20	792557	2·66	894546	1·66	898010	4·33	101990	40
21	9·792716	2·66	9·894446	1·67	9·898270	4·33	10·101730	39
22	792876	2·66	894346	1·67	898530	4·33	101470	38
23	793035	2·66	894246	1·67	898789	4·33	101211	37
24	793195	2·65	894146	1·67	899049	4·32	100951	36
25	793354	2·65	894046	1·67	899308	4·32	100692	35
26	793514	2·65	893946	1·67	899568	4·32	100432	34
27	793673	2·65	893846	1·67	899827	4·32	100173	33
28	793832	2·65	893745	1·67	900086	4·32	099914	32
29	793991	2·65	893645	1·67	900346	4·32	099654	31
30	794150	2·64	893544	1·67	900605	4·32	099395	30
31	9·794308	2·64	9·893444	1·68	9·900864	4·32	10·099136	29
32	794467	2·64	893343	1·68	901124	4·32	098876	28
33	794626	2·64	893243	1·68	901383	4·32	098617	27
34	794784	2·64	893142	1·68	901642	4·32	098358	26
35	794942	2·64	893041	1·68	901901	4·32	098099	25
36	795101	2·64	892940	1·68	902160	4·32	097840	24
37	795259	2·63	892839	1·68	902419	4·32	097581	23
38	795417	2·63	892739	1·68	902679	4·32	097321	22
39	795575	2·63	892638	1·68	902938	4·32	097062	21
40	795733	2·63	892536	1·68	903197	4·31	096803	20
41	9·795891	2·63	9·892435	1·69	9·903455	4·31	10·096545	19
42	796049	2·63	892334	1·69	903714	4·31	096286	18
43	796206	2·63	892233	1·69	903973	4·31	096027	17
44	796364	2·62	892132	1·69	904232	4·31	095768	16
45	796521	2·62	892030	1·69	904491	4·31	095509	15
46	796679	2·62	891929	1·69	904750	4·31	095250	14
47	796836	2·62	891827	1·69	905008	4·31	094992	13
48	796993	2·62	891726	1·69	905267	4·31	094733	12
49	797150	2·61	891624	1·69	905526	4·31	094474	11
50	797307	2·61	891523	1·70	905784	4·31	094216	10
51	9·797464	2·61	9·891421	1·70	9·906043	4·31	10·093957	9
52	797621	2·61	891319	1·70	906302	4·31	093698	8
53	797777	2·61	891217	1·70	906560	4·31	093440	7
54	797934	2·61	891115	1·70	906819	4·31	093181	6
55	798091	2·61	891013	1·70	907077	4·31	092923	5
56	798247	2·61	890911	1·70	907336	4·31	092664	4
57	798403	2·60	890809	1·70	907594	4·31	092406	3
58	798560	2·60	890707	1·70	907852	4·31	092148	2
59	798716	2·60	890605	1·70	908111	4·30	091889	1
60	798871	2·60	890503	1·70	908369	4·30	091631	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

(51 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·798872	2·60	9·890503	1·70	9·908369	4·30	10·091631	60
1	799028	2·60	890400	1·71	908628	4·30	091372	59
2	799184	2·60	890298	1·71	908886	4·30	091114	58
3	799339	2·59	890195	1·71	909144	4·30	090856	57
4	799495	2·59	890093	1·71	909402	4·30	090598	56
5	799651	2·59	889990	1·71	909660	4·30	090340	55
6	799806	2·59	889888	1·71	909918	4·30	090082	54
7	799962	2·59	889785	1·71	910177	4·30	089823	53
8	800117	2·59	889682	1·71	910435	4·30	089565	52
9	800272	2·58	889579	1·71	910693	4·30	089307	51
10	800427	2·58	889477	1·71	910951	4·30	089049	50
11	9·800582	2·58	9·889374	1·72	9·911209	4·30	10·088791	49
12	800737	2·58	889271	1·72	911467	4·30	088533	48
13	800892	2·58	889168	1·72	911724	4·30	088276	47
14	801047	2·58	889064	1·72	911982	4·30	088018	46
15	801201	2·58	888961	1·72	912240	4·30	087760	45
16	801356	2·57	888858	1·72	912498	4·30	087502	44
17	801511	2·57	888755	1·72	912756	4·30	087244	43
18	801665	2·57	888651	1·72	913014	4·29	086986	42
19	801819	2·57	888548	1·72	913271	4·29	086729	41
20	801973	2·57	888444	1·73	913529	4·29	086471	40
21	9·802128	2·57	9·888341	1·73	9·913787	4·29	10·086213	39
22	802282	2·56	888237	1·73	914044	4·29	085956	38
23	802436	2·56	888134	1·73	914302	4·29	085698	37
24	802589	2·56	888030	1·73	914560	4·29	085440	36
25	802743	2·56	887926	1·73	914817	4·29	085183	35
26	802897	2·56	887622	1·73	915075	4·29	084925	34
27	803050	2·56	887718	1·73	915332	4·29	084668	33
28	803204	2·56	887614	1·73	915590	4·29	084410	32
29	803357	2·55	887510	1·73	915847	4·29	084153	31
30	803511	2·55	887406	1·74	916104	4·29	083896	30
31	9·803664	2·55	9·887302	1·74	9·916362	4·29	10·083638	29
32	803817	2·55	887198	1·74	916619	4·29	083381	28
33	803970	2·55	887093	1·74	916877	4·29	083123	27
34	804123	2·55	886989	1·74	917134	4·29	082866	26
35	804276	2·54	886885	1·74	917391	4·29	082609	25
36	804428	2·54	886780	1·74	917648	4·29	082352	24
37	804581	2·54	886676	1·74	917905	4·29	082095	23
38	804734	2·54	886571	1·74	918163	4·28	081837	22
39	804886	2·54	886466	1·74	918420	4·28	081580	21
40	805039	2·54	886362	1·75	918677	4·28	081323	20
41	9·805191	2·54	9·886257	1·75	9·918934	4·28	10·081066	19
42	805343	2·53	886152	1·75	919191	4·28	080809	18
43	805495	2·53	886047	1·75	919448	4·28	080552	17
44	805647	2·53	885942	1·75	919705	4·28	080295	16
45	805799	2·53	885837	1·75	919962	4·28	080038	15
46	805951	2·53	885732	1·75	920219	4·28	079781	14
47	806103	2·53	885627	1·75	920476	4·28	079524	13
48	806254	2·53	885522	1·75	920733	4·28	079267	12
49	806406	2·52	885416	1·75	920990	4·28	079010	11
50	806557	2·52	885311	1·76	921247	4·28	078753	10
51	9·806709	2·52	9·885205	1·76	9·921503	4·28	10·078497	9
52	806860	2·52	885100	1·76	921760	4·28	078240	8
53	807011	2·52	884994	1·76	922017	4·28	077983	7
54	807163	2·52	884889	1·76	922274	4·28	077726	6
55	807314	2·52	884783	1·76	922530	4·28	077470	5
56	807465	2·51	884677	1·76	922787	4·28	077213	4
57	807615	2·51	884572	1·76	923044	4·28	076956	3
58	807766	2·51	884466	1·76	923300	4·28	076700	2
59	807917	2·51	884360	1·76	923557	4·27	076443	1
60	808067	2·51	884254	1·77	923813	4·27	076187	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

(50 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·808067	2·51	9·884254	1·77	9·923813	4·27	10·076187	60
1	808218	2·51	884148	1·77	924070	4·27	075930	59
2	808368	2·51	884042	1·77	924327	4·27	075673	58
3	808519	2·50	883936	1·77	924583	4·27	075417	57
4	808669	2·50	883829	1·77	924840	4·27	075160	56
5	808819	2·50	883723	1·77	925096	4·27	074904	55
6	808969	2·50	883617	1·77	925352	4·27	074648	54
7	809119	2·50	883510	1·77	925609	4·27	074391	53
8	809269	2·50	883404	1·77	925865	4·27	074135	52
9	809419	2·49	883297	1·78	926122	4·27	073878	51
10	809569	2·49	883191	1·78	926378	4·27	073622	50
11	9·809718	2·49	9·883084	1·78	9·926634	4·27	10·073366	49
12	809868	2·49	882977	1·78	926890	4·27	073110	48
13	810017	2·49	882871	1·78	927147	4·27	072853	47
14	810167	2·49	882764	1·78	927403	4·27	072597	46
15	810316	2·48	882657	1·78	927659	4·27	072341	45
16	810465	2·48	882550	1·78	927915	4·27	072085	44
17	810614	2·48	882443	1·78	928171	4·27	071829	43
18	810763	2·48	882336	1·79	928427	4·27	071573	42
19	810912	2·48	882229	1·79	928683	4·27	071317	41
20	811061	2·48	882121	1·79	928940	4·27	071060	40
21	9·811210	2·48	9·882014	1·79	9·929196	4·27	10·070804	39
22	811358	2·47	881907	1·79	929452	4·27	070548	38
23	811507	2·47	881799	1·79	929708	4·27	070292	37
24	811655	2·47	881692	1·79	929964	4·26	070036	36
25	811804	2·47	881584	1·79	930220	4·26	069780	35
26	811952	2·47	881477	1·79	930475	4·26	069525	34
27	812100	2·47	881369	1·79	930731	4·26	069269	33
28	812248	2·47	881261	1·80	930987	4·26	069013	32
29	812396	2·46	881153	1·80	931243	4·26	068757	31
30	812544	2·46	881046	1·80	931499	4·26	068501	30
31	9·812692	2·46	9·880938	1·80	9·931755	4·26	10·068245	29
32	812840	2·46	880830	1·80	932010	4·26	067990	28
33	812988	2·46	880722	1·80	932266	4·26	067734	27
34	813135	2·46	880613	1·80	932522	4·26	067478	26
35	813283	2·46	880505	1·80	932778	4·26	067222	25
36	813430	2·45	880397	1·80	933033	4·26	066967	24
37	813578	2·45	880289	1·81	933289	4·26	066711	23
38	813725	2·45	880180	1·81	933545	4·26	066455	22
39	813872	2·45	880072	1·81	933800	4·26	066200	21
40	814019	2·45	879963	1·81	934056	4·26	065944	20
41	9·814166	2·45	9·879855	1·81	9·934311	4·26	10·065689	19
42	814313	2·45	879746	1·81	934567	4·26	065433	18
43	814460	2·44	879637	1·81	934823	4·26	065177	17
44	814607	2·44	879529	1·81	935078	4·26	064922	16
45	814753	2·44	879420	1·81	935333	4·26	064667	15
46	814900	2·44	879311	1·81	935589	4·26	064411	14
47	815046	2·44	879202	1·82	935844	4·26	064156	13
48	815193	2·44	879093	1·82	936100	4·26	063900	12
49	815339	2·44	878984	1·82	936355	4·26	063645	1
50	815485	2·43	878875	1·82	936610	4·26	063390	0
51	9·815631	2·43	9·878766	1·82	9·936866	4·25	10·063134	9
52	815778	2·43	878656	1·82	937121	4·25	062879	8
53	815924	2·43	878547	1·82	937376	4·25	062624	7
54	816069	2·43	878438	1·82	937632	4·25	062368	6
55	816215	2·43	878328	1·82	937887	4·25	062113	5
56	816361	2·43	878219	1·83	938142	4·25	061858	4
57	816507	2·42	878109	1·83	938398	4·25	061602	3
58	816652	2·42	877999	1·83	938653	4·25	061347	2
59	816798	2·42	877890	1·83	938908	4·25	061092	1
60	816943	2·42	877780	1·83	939163	4·25	060837	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

(49 DEGREES.)

Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
9·816943	2·42	9·877780	1·83	9·939163	4·25	10·060837	60
817088	2·42	877670	1·83	939418	4·25	060582	59
817233	2·42	877560	1·83	939673	4·25	060327	58
817379	2·42	877450	1·83	939928	4·25	060072	57
817524	2·41	877340	1·83	940183	4·25	059817	56
817668	2·41	877230	1·84	940438	4·25	059562	55
817813	2·41	877120	1·84	940694	4·25	059306	54
817958	2·41	877010	1·84	940949	4·25	059051	53
818103	2·41	876899	1·84	941204	4·25	058796	52
818247	2·41	876789	1·84	941458	4·25	058542	51
818392	2·41	876678	1·84	941714	4·25	058286	50
9·818536	2·40	9·876568	1·84	9·941968	4·25	10·058032	49
818681	2·40	876457	1·84	942223	4·25	057777	48
818825	2·40	876347	1·84	942478	4·25	057522	47
818969	2·40	876236	1·85	942733	4·25	057267	46
819113	2·40	876125	1·85	942988	4·25	057012	45
819257	2·40	876014	1·85	943243	4·25	056757	44
819401	2·40	875904	1·85	943498	4·25	056502	43
819545	2·39	875793	1·85	943752	4·25	056248	42
819689	2·39	875682	1·85	944007	4·25	055993	41
819832	2·39	875571	1·85	944262	4·25	055738	40
9·819976	2·39	9·875459	1·85	9·944517	4·25	10·055483	39
820120	2·39	875348	1·85	944771	4·24	055229	38
820263	2·39	875237	1·85	945026	4·24	054974	37
820406	2·39	875126	1·86	945281	4·24	054719	36
820550	2·38	875014	1·86	945535	4·24	054465	35
820693	2·38	874903	1·86	945790	4·24	054210	34
820836	2·38	874791	1·86	946045	4·24	053955	33
820979	2·38	874680	1·86	946299	4·24	053701	32
821122	2·38	874568	1·86	946554	4·24	053446	31
821265	2·38	874456	1·86	946808	4·24	053192	30
9·821407	2·38	9·874344	1·86	9·947063	4·24	10·052937	29
821550	2·38	874232	1·87	947318	4·24	052682	28
821693	2·37	874121	1·87	947572	4·24	052428	27
821835	2·37	874009	1·87	947826	4·24	052174	26
821977	2·37	873896	1·87	948081	4·24	051919	25
822120	2·37	873784	1·87	948336	4·24	051664	24
822262	2·37	873672	1·87	948590	4·24	051410	23
822404	2·37	873560	1·87	948844	4·24	051156	22
822546	2·37	873448	1·87	949099	4·24	050901	21
822688	2·36	873335	1·87	949353	4·24	050647	20
9·822830	2·36	9·873223	1·87	9·949607	4·24	10·050393	19
822972	2·36	873110	1·88	949862	4·24	050138	18
823114	2·36	872998	1·88	950116	4·24	049884	17
823255	2·36	872885	1·88	950370	4·24	049630	16
823397	2·36	872772	1·88	950625	4·24	049375	15
823539	2·36	872659	1·88	950879	4·24	049121	14
823680	2·35	872547	1·88	951133	4·24	048867	13
823821	2·35	872434	1·88	951388	4·24	048612	12
823963	2·35	872321	1·88	951642	4·24	048358	11
824104	2·35	872208	1·88	951896	4·24	048104	10
9·824245	2·35	9·872095	1·89	9·952150	4·24	10·047850	9
824386	2·35	871981	1·89	952405	4·24	047595	8
824527	2·35	871868	1·89	952659	4·24	047341	7
824668	2·34	871755	1·89	952913	4·24	047087	6
824808	2·34	871641	1·89	953167	4·23	046833	5
824949	2·34	871528	1·89	953421	4·23	046579	4
825090	2·34	871414	1·89	953675	4·23	046325	3
825230	2·34	871301	1·89	953929	4·23	046071	2
825371	2·34	871187	1·89	954183	4·23	045817	1
825511	2·34	871073	1·90	954437	4·23	045563	0
Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·825511	2·34	9·871073	1·90	9·954437	4·23	10·045563	60
1	825651	2·33	870960	1·90	954691	4·23	045309	59
2	825791	2·33	870846	1·90	954945	4·23	045055	58
3	825931	2·33	870732	1·90	955200	4·23	044800	57
4	826071	2·33	870618	1·90	955454	4·23	044546	56
5	826211	2·33	870504	1·90	955707	4·23	044293	55
6	826351	2·33	870390	1·90	955961	4·23	044039	54
7	826491	2·33	870276	1·90	956215	4·23	043785	53
8	826631	2·33	870161	1·90	956469	4·23	043531	52
9	826770	2·32	870047	1·91	956723	4·23	043277	51
10	826910	2·32	869933	1·91	956977	4·23	043023	50
11	9·827049	2·32	9·869818	1·91	9·957231	4·23	10·042769	49
12	827189	2·32	869704	1·91	957485	4·23	042515	48
13	827328	2·32	869589	1·91	957739	4·23	042261	47
14	827467	2·32	869474	1·91	957993	4·23	042007	46
15	827606	2·32	869360	1·91	958246	4·23	041754	45
16	827745	2·32	869245	1·91	958500	4·23	041500	44
17	827884	2·31	869130	1·91	958754	4·23	041246	43
18	828023	2·31	869015	1·92	959008	4·23	040992	42
19	828162	2·31	868900	1·92	959262	4·23	040738	41
20	828301	2·31	868785	1·92	959516	4·23	040484	40
21	9·828439	2·31	9·868670	1·92	9·959769	4·23	10·040231	39
22	828578	2·31	868555	1·92	960023	4·23	039977	38
23	828716	2·31	868440	1·92	960277	4·23	039723	37
24	828855	2·30	868324	1·92	960531	4·23	039469	36
25	828993	2·30	868209	1·92	960784	4·23	039216	35
26	829131	2·30	868093	1·92	961038	4·23	038962	34
27	829269	2·30	867978	1·93	961291	4·23	038709	33
28	829407	2·30	867862	1·93	961545	4·23	038455	32
29	829545	2·30	867747	1·93	961799	4·23	038201	31
30	829683	2·30	867631	1·93	962052	4·23	037948	30
31	9·829821	2·29	9·867515	1·93	9·962306	4·23	10·037694	29
32	829959	2·29	867399	1·93	962560	4·23	037440	28
33	830097	2·29	867283	1·93	962813	4·23	037187	27
34	830234	2·29	867167	1·93	963067	4·23	036933	26
35	830372	2·29	867051	1·93	963320	4·23	036680	25
36	830509	2·29	866935	1·94	963574	4·23	036426	24
37	830646	2·29	866819	1·94	963827	4·23	036173	23
38	830784	2·29	866703	1·94	964081	4·23	035919	22
39	830921	2·28	866586	1·94	964335	4·23	035665	21
40	831058	2·28	866470	1·94	964588	4·22	035412	20
41	9·831195	2·28	9·866353	1·94	9·964842	4·22	10·035158	19
42	831332	2·28	866237	1·94	965095	4·22	034905	18
43	831469	2·28	866120	1·94	965349	4·22	034651	17
44	831606	2·28	866004	1·95	965602	4·22	034398	16
45	831742	2·28	865887	1·95	965855	4·22	034145	15
46	831879	2·28	865770	1·95	966105	4·22	033891	14
47	832015	2·27	865653	1·95	966362	4·22	033638	13
48	832152	2·27	865536	1·95	966616	4·22	033384	12
49	832288	2·27	865419	1·95	966869	4·22	033131	11
50	832425	2·27	865302	1·95	967123	4·22	032877	10
51	9·832561	2·27	9·865185	1·95	9·967376	4·22	10·032624	9
52	832697	2·27	865068	1·95	967629	4·22	032371	8
53	832833	2·27	864950	1·95	967883	4·22	032117	7
54	832969	2·26	864833	1·96	968136	4·22	031864	6
55	833105	2·26	864716	1·96	968389	4·22	031611	5
56	833241	2·26	864598	1·96	968643	4·22	031357	4
57	833377	2·26	864481	1·96	968896	4·22	031104	3
58	833512	2·26	864363	1·96	969149	4·22	030851	2
59	833648	2·26	864245	1·96	969403	4·22	030597	1
60	833783	2·26	864127	1·96	969656	4·22	030344	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·833783	2·26	9·864127	1·96	9·969656	4·22	10·030344	60
1	833919	2·25	864010	1·96	969909	4·22	030091	59
2	834054	2·25	863892	1·97	970162	4·22	029838	58
3	834189	2·25	863774	1·97	970416	4·22	029584	57
4	834325	2·25	863656	1·97	970669	4·22	029331	56
5	834460	2·25	863538	1·97	970922	4·22	029078	55
6	834595	2·25	863419	1·97	971175	4·22	028825	54
7	834730	2·25	863301	1·97	971429	4·22	028571	53
8	834865	2·25	863183	1·97	971682	4·22	028318	52
9	834999	2·24	863064	1·97	971935	4·22	028065	51
10	835134	2·24	862946	1·98	972188	4·22	027812	50
11	9·835269	2·24	9·862827	1·98	9·972441	4·22	10·027559	49
12	835403	2·24	862709	1·98	972694	4·22	027306	48
13	835538	2·24	862590	1·98	972948	4·22	027052	47
14	835672	2·24	862471	1·98	973201	4·22	026799	46
15	835807	2·24	862353	1·98	973454	4·22	026546	45
16	835941	2·24	862234	1·98	973707	4·22	026293	44
17	836075	2·23	862115	1·98	973960	4·22	026040	43
18	836209	2·23	861996	1·98	974213	4·22	025787	42
19	836343	2·23	861877	1·98	974466	4·22	025534	41
20	836477	2·23	861758	1·99	974719	4·22	025281	40
21	9·836611	2·23	9·861638	1·99	9·974973	4·22	10·025027	39
22	836745	2·23	861519	1·99	975226	4·22	024774	38
23	836878	2·23	861400	1·99	975479	4·22	024521	37
24	837012	2·22	861280	1·99	975732	4·22	024268	36
25	837146	2·22	861161	1·99	975985	4·22	024015	35
26	837279	2·22	861041	1·99	976238	4·22	023762	34
27	837412	2·22	860922	1·99	976491	4·22	023509	33
28	837546	2·22	860802	1·99	976744	4·22	023256	32
29	837679	2·22	860682	2·00	976997	4·22	023003	31
30	837812	2·22	860562	2·00	977250	4·22	022750	30
31	9·837945	2·22	9·860442	2·00	9·977503	4·22	10·022497	29
32	838078	2·21	860322	2·00	977756	4·22	022244	28
33	838211	2·21	860202	2·00	978009	4·22	021991	27
34	838344	2·21	860082	2·00	978262	4·22	021738	26
35	838477	2·21	859962	2·00	978515	4·22	021485	25
36	838610	2·21	859842	2·00	978768	4·22	021232	24
37	838742	2·21	859721	2·01	979021	4·22	020979	23
38	838875	2·21	859601	2·01	979274	4·22	020726	22
39	839007	2·21	859480	2·01	979527	4·22	020473	21
40	839140	2·20	859360	2·01	979780	4·22	020220	20
41	9·839272	2·20	9·859239	2·01	9·980033	4·22	10·019967	19
42	839404	2·20	859119	2·01	980286	4·22	019714	18
43	839536	2·20	858998	2·01	980538	4·22	019462	17
44	839668	2·20	858877	2·01	980791	4·21	019209	16
45	839800	2·20	858756	2·02	981044	4·21	018956	15
46	839932	2·20	858635	2·02	981297	4·21	018703	14
47	840064	2·19	858514	2·02	981550	4·21	018450	13
48	840196	2·19	858393	2·02	981803	4·21	018197	12
49	840328	2·19	858272	2·02	982056	4·21	017944	11
50	840459	2·19	858151	2·02	982309	4·21	017691	10
51	9·840591	2·19	9·858029	2·02	9·982562	4·21	10·017438	9
52	840722	2·19	857908	2·02	982814	4·21	017186	8
53	840854	2·19	857786	2·02	983067	4·21	016933	7
54	840985	2·19	857665	2·03	983320	4·21	016680	6
55	841116	2·18	857543	2·03	983573	4·21	016427	5
56	841247	2·18	857422	2·03	983826	4·21	016174	4
57	841378	2·18	857300	2·03	984079	4·21	015921	3
58	841509	2·18	857178	2·03	984331	4·21	015669	2
59	841640	2·18	857056	2·03	984584	4·21	015416	1
60	841771	2·18	856934	2·03	984837	4·21	015163	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

(46 DEGREES.)

M.	Sine	D.	Cosine	D.	Tang.	D.	Cotang.	
0	9·841771	2·18	9·856934	2·03	9·984837	4·21	10·015163	60
1	841902	2·18	856812	2·03	985090	4·21	014910	59
2	842033	2·18	856690	2·04	985343	4·21	014657	58
3	842163	2·17	856568	2·04	985596	4·21	014404	57
4	842294	2·17	856446	2·04	985848	4·21	014152	56
5	842424	2·17	856323	2·04	986101	4·21	013899	55
6	842555	2·17	856201	2·04	986354	4·21	013646	54
7	842685	2·17	856078	2·04	986607	4·21	013393	53
8	842815	2·17	855956	2·04	986860	4·21	013140	52
9	842946	2·17	855833	2·04	987112	4·21	012888	51
10	843076	2·17	855711	2·05	987365	4·21	012635	50
11	9·843206	2·16	9·855588	2·05	9·987618	4·21	10·012382	49
12	843336	2·16	855465	2·05	987871	4·21	012129	48
13	843466	2·16	855342	2·05	988123	4·21	011877	47
14	843595	2·16	855219	2·05	988376	4·21	011624	46
15	843725	2·16	855096	2·05	988629	4·21	011371	45
16	843855	2·16	854973	2·05	988882	4·21	011118	44
17	843984	2·16	854850	2·05	989134	4·21	010866	43
18	844114	2·15	854727	2·06	989387	4·21	010613	42
19	844243	2·15	854603	2·06	989640	4·21	010360	41
20	844372	2·15	854480	2·06	989893	4·21	010107	40
21	9·844502	2·15	9·854356	2·06	9·990145	4·21	10·009855	39
22	844631	2·15	854233	2·06	990398	4·21	009602	38
23	844760	2·15	854109	2·06	990651	4·21	009349	37
24	844889	2·15	853986	2·06	990903	4·21	009097	36
25	845018	2·15	853862	2·06	991156	4·21	008844	35
26	845147	2·15	853738	2·06	991409	4·21	008591	34
27	845276	2·14	853614	2·07	991662	4·21	008338	33
28	845405	2·14	853490	2·07	991914	4·21	008086	32
29	845533	2·14	853366	2·07	992167	4·21	007833	31
30	845662	2·14	853242	2·07	992420	4·21	007580	30
31	9·845790	2·14	9·853118	2·07	9·992672	4·21	10·007328	29
32	845919	2·14	852994	2·07	992925	4·21	007075	28
33	846047	2·14	852869	2·07	993178	4·21	006822	27
34	846175	2·14	852745	2·07	993430	4·21	006570	26
35	846304	2·14	852620	2·07	993683	4·21	006317	25
36	846432	2·13	852496	2·08	993936	4·21	006064	24
37	846560	2·13	852371	2·08	994189	4·21	005811	23
38	846688	2·13	852247	2·08	994441	4·21	005559	22
39	846816	2·13	852122	2·08	994694	4·21	005306	21
40	846944	2·13	851997	2·08	994947	4·21	005053	20
41	9·847071	2·13	9·851872	2·08	9·995199	4·21	10·004801	19
42	847199	2·13	851747	2·08	995452	4·21	004548	18
43	847327	2·13	851622	2·08	995705	4·21	004295	17
44	847454	2·12	851497	2·09	995957	4·21	004043	16
45	847582	2·12	851372	2·09	996210	4·21	003790	15
46	847709	2·12	851246	2·09	996463	4·21	003537	14
47	847836	2·12	851121	2·09	996715	4·21	003285	13
48	847964	2·12	850996	2·09	996968	4·21	003032	12
49	848091	2·12	850870	2·09	997221	4·21	002779	11
50	848218	2·12	850745	2·09	997473	4·21	002527	10
51	9·848345	2·12	9·850619	2·09	9·997726	4·21	10·002274	9
52	848472	2·11	850493	2·10	997979	4·21	002021	8
53	848599	2·11	850368	2·10	998231	4·21	001769	7
54	848726	2·11	850242	2·10	998484	4·21	001516	6
55	848852	2·11	850116	2·10	998737	4·21	001263	5
56	848979	2·11	849990	2·10	998989	4·21	001011	4
57	849106	2·11	849864	2·10	999242	4·21	000758	3
58	849232	2·11	849738	2·10	999495	4·21	000505	2
59	849359	2·11	849611	2·10	999748	4·21	000253	1
60	849485	2·11	849485	2·10	10·000000	4·21	10·000000	0
	Cosine	D.	Sine	D.	Cotang.	D.	Tang.	M.

(45 DEGREES.)

	0 Deg.		1 Deg.		2 Deg.		3 Deg.		4 Deg.		
M	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	M
0	00000	Unit.	01745	99985	03490	99939	05234	99863	06976	99756	60
1	00029	1·0000	01774	99984	03519	99938	05263	99861	07005	99754	59
2	00058	1·0000	01803	99984	03548	99937	05292	99860	07034	99752	58
3	00087	1·0000	01832	99983	03577	99936	05321	99858	07063	99750	57
4	00116	1·0000	01862	99983	03606	99935	05350	99857	07092	99748	56
5	00145	1·0000	01891	99982	03635	99934	05379	99855	07121	99746	55
6	00175	1·0000	01920	99982	03664	99933	05408	99854	07150	99744	54
7	00204	1·0000	01949	99981	03693	99932	05437	99852	07179	99742	53
8	00233	1·0000	01978	99980	03723	99931	05466	99851	07208	99740	52
9	00262	1·0000	02007	99980	03752	99930	05495	99849	07237	99738	51
10	00291	1·0000	02036	99979	03781	99929	05524	99847	07266	99736	50
11	00320	99999	02065	99979	03810	99927	05553	99846	07295	99734	49
12	00349	99999	02094	99978	03839	99926	05582	99844	07324	99731	48
13	00378	99999	02123	99977	03868	99925	05611	99842	07353	99729	47
14	00407	99999	02152	99977	03897	99924	05640	99841	07382	99727	46
15	00436	99999	02181	99976	03926	99923	05669	99839	07411	99725	45
16	00465	99999	02211	99976	03955	99922	05698	99838	07440	99723	44
17	00495	99999	02240	99975	03984	99921	05727	99836	07469	99721	43
18	00524	99999	02269	99974	04013	99919	05756	99834	07498	99719	42
19	00553	99998	02298	99974	04042	99918	05785	99833	07527	99716	41
20	00582	99998	02327	99973	04071	99917	05814	99831	07556	99714	40
21	00611	99998	02356	99972	04100	99916	05844	99829	07585	99712	39
22	00640	99998	02385	99972	04129	99915	05873	99827	07614	99710	38
23	00669	99998	02414	99971	04159	99913	05902	99826	07643	99708	37
24	00698	99998	02443	99970	04188	99912	05931	99824	07672	99705	36
25	00727	99997	02472	99969	04217	99911	05960	99822	07701	99703	35
26	00756	99997	02501	99969	04246	99910	05989	99821	07730	99701	34
27	00785	99997	02530	99968	04275	99909	06018	99819	07759	99699	33
28	00814	99997	02560	99967	04304	99907	06047	99817	07788	99696	32
29	00844	99996	02589	99966	04333	99906	06076	99815	07817	99694	31
30	00873	99996	02618	99966	04362	99905	06105	99813	07846	99692	30
31	00902	99996	02647	99965	04391	99904	06134	99812	07875	99689	29
32	00931	99996	02676	99964	04420	99902	06163	99810	07904	99687	28
33	00960	99995	02705	99963	04449	99901	06192	99808	07933	99685	27
34	00989	99995	02734	99963	04478	99900	06221	99806	07962	99683	26
35	01018	99995	02763	99962	04507	99898	06250	99804	07991	99680	25
36	01047	99995	02792	99961	04536	99897	06279	99803	08020	99678	24
37	01076	99994	02821	99960	04565	99896	06308	99801	08049	99676	23
38	01105	99994	02850	99959	04594	99894	06337	99799	08078	99673	22
39	01134	99994	02879	99959	04623	99893	06366	99797	08107	99671	21
40	01164	99993	02008	99958	04653	99892	06395	99795	08136	99668	20
41	01193	99993	02938	99957	04682	99890	06424	99793	08165	99666	19
42	01222	99993	02967	99956	04711	99889	06453	99792	08194	99664	18
43	01251	99992	02996	99955	04740	99888	06482	99790	08223	99661	17
44	01280	99992	03025	99954	04769	99886	06511	99788	08252	99659	16
45	01309	99991	03054	99953	04798	99885	06540	99786	08281	99657	15
46	01338	99991	03083	99952	04827	99883	06569	99784	08310	99654	14
47	01367	99991	03112	99952	04856	99882	06598	99782	08339	99652	13
48	01396	99990	03141	99951	04885	99881	06627	99780	08368	99649	12
49	01425	99990	03170	99950	04914	99879	06656	99778	08397	99647	11
50	01454	99989	03199	99949	04943	99878	06685	99776	08426	99644	10
51	01483	99989	03228	99948	04972	99876	06714	99774	08455	99642	9
52	01513	99989	03257	99947	05001	99875	06743	99772	08484	99639	8
53	01542	99988	03286	99946	05030	99873	06773	99770	08513	99637	7
54	01571	99988	03316	99945	05059	99872	06802	99768	08542	99635	6
55	01600	99987	03345	99944	05088	99870	06831	99766	08571	99632	5
56	01629	99987	03374	99943	05117	99869	06860	99764	08600	99630	4
57	01658	99986	03403	99942	05146	99867	06889	99762	08629	99627	3
58	01687	99986	03432	99941	05175	99866	06918	99760	08658	99625	2
59	01716	99985	03461	99940	05205	99864	06947	99758	08687	99622	1
M	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S	M
	89 Deg.		88 Deg.		87 Deg.		86 Deg.		85 Deg.		

M	5 Deg.		6 Deg.		7 Deg.		8 Deg.		9 Deg.		
M	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S	S.	C S.	M
0	08716	99619	10453	99452	12187	99255	13917	99027	15643	98769	60
1	08745	99617	10482	99449	12216	99251	13946	99023	15672	98764	59
2	08774	99614	10511	99446	12245	99248	13975	99019	15701	98760	58
3	08803	99612	10540	99443	12274	99244	14004	99015	15730	98755	57
4	08831	99609	10569	99440	12302	99240	14033	99011	15758	98751	56
5	08860	99607	10597	99437	12331	99237	14061	99006	15787	98746	55
6	08889	99604	10626	99434	12360	99233	14090	99002	15816	98741	54
7	08918	99602	10655	99431	12389	99230	14119	98998	15845	98737	53
8	08947	99599	10684	99428	12418	99226	14148	98994	15873	98732	52
9	08976	99596	10713	99424	12447	99222	14177	98990	15902	98728	51
10	09005	99594	10742	99421	12476	99219	14205	98986	15931	98723	50
11	09034	99591	10771	99418	12504	99215	14234	98982	15959	98718	49
12	09063	99588	10800	99415	12533	99211	14263	98978	15988	98714	48
13	09092	99586	10829	99412	12562	99208	14292	98973	16017	98709	47
14	09121	99583	10858	99409	12591	99204	14320	98969	16046	98704	46
15	09150	99580	10887	99406	12620	99200	14349	98965	16074	98700	45
16	09179	99578	10916	99402	12649	99197	14378	98961	16103	98695	44
17	09208	99575	10945	99399	12678	99193	14407	98957	16132	98690	43
18	09237	99572	10973	99396	12706	99189	14436	98953	16160	98686	42
19	09266	99570	11002	99393	12735	99186	14464	98948	16189	98681	41
20	09295	99567	11031	99390	12764	99182	14493	98944	16218	98676	40
21	09324	99564	11060	99386	12793	99178	14522	98940	16246	98671	39
22	09353	99562	11089	99383	12822	99175	14551	98936	16275	98667	38
23	09382	99559	11118	99380	12851	99171	14580	98931	16304	98662	37
24	09411	99556	11147	99377	12880	99167	14608	98927	16333	98657	36
25	09440	99553	11176	99374	12908	99163	14637	98923	16361	98652	35
26	09469	99551	11205	99370	12937	99160	14666	98919	16390	98648	34
27	09498	99548	11234	99367	12966	99156	14695	98914	16419	98643	33
28	09527	99545	11263	99364	12995	99152	14723	98910	16447	98638	32
29	09556	99542	11291	99360	13024	99148	14752	98906	16476	98633	31
30	09585	99540	11320	99357	13053	99144	14781	98902	16505	98629	30
31	09614	99537	11349	99354	13081	99141	14810	98897	16533	98624	29
32	09642	99534	11378	99351	13110	99137	14838	98893	16562	98619	28
33	09671	99531	11407	99347	13139	99133	14867	98889	16591	98614	27
34	09700	99528	11436	99344	13168	99129	14896	98884	16620	98609	26
35	09729	99526	11465	99341	13197	99125	14925	98880	16648	98604	25
36	09758	99523	11494	99337	13226	99122	14954	98876	16677	98600	24
37	09787	99520	11523	99334	13254	99118	14982	98871	16706	98595	23
38	09816	99517	11552	99331	13283	99114	15011	98867	16734	98590	22
39	09845	99514	11580	99327	13312	99110	15040	98863	16763	98585	21
40	09874	99511	11609	99324	13341	99106	15069	98858	16792	98580	20
41	09903	99508	11638	99320	13370	99102	15097	98854	16820	98575	19
42	09932	99506	11667	99317	13399	99098	15126	98849	16849	98570	18
43	09961	99503	11696	99314	13427	99094	15155	98845	16878	98565	17
44	09990	99500	11725	99310	13456	99091	15184	98841	16906	98561	16
45	10019	99497	11754	99307	13485	99087	15212	98836	16935	98556	15
46	10048	99494	11783	99303	13514	99083	15241	98832	16964	98551	14
47	10077	99491	11812	99300	13543	99079	15270	98827	16992	98545	13
48	10106	99488	11840	99297	13572	99075	15292	98823	17021	98541	12
49	10135	99485	11869	99293	13600	99071	15327	98818	17050	98536	11
50	10164	99482	11898	99290	13629	99067	15356	98814	17078	98531	10
51	10192	99479	11927	99286	13658	99063	15385	98809	17107	98526	9
52	10221	99476	11956	99283	13087	99059	15414	98805	17136	98521	8
53	10250	99473	11985	99279	13716	99055	15442	98800	17164	98516	7
54	10279	99470	12014	99276	13744	99051	15471	98796	17193	98511	6
55	10308	99467	12043	99272	13773	99047	15500	98791	17222	98506	5
56	10337	99464	12071	99269	13802	99043	15529	98787	17250	98501	4
57	10366	99461	12100	99265	13831	99039	15557	98782	172 9	98496	3
58	10395	99458	12129	99262	13860	99035	15586	98778	17308	98491	2
59	10424	99455	12158	99258	13889	99031	15615	98773	17336	98486	1
M	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	M
	84 Deg.		88 Deg.		82 Deg.		81 Deg		80 Deg		

	10 Deg.		11 Deg.		12 Deg.		13 Deg.		14 Deg.		
M	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	M
0	17365	98481	19081	98163	20791	97815	22495	97437	24192	97030	60
1	17393	98476	19109	98157	20820	97809	22523	97430	24220	97023	59
2	17422	98471	19138	98152	20848	97803	22552	97424	24249	97015	58
3	17451	98466	19167	98146	20877	97797	22580	97417	24277	97008	57
4	17479	98461	19195	98140	20905	97791	22608	97411	24305	97001	56
5	17508	98455	19224	98135	20933	97784	22637	97404	24333	96994	55
6	17537	98450	19252	98129	20962	97778	22665	97398	24362	96987	54
7	17565	98445	19281	98124	20990	97772	22693	97391	24390	96980	53
8	17594	98440	19309	98118	21019	97766	22722	97384	24418	96973	52
9	17623	98435	19338	98112	21047	97760	22750	97378	24446	96966	51
10	17651	98430	19366	98107	21076	97754	22778	97371	24474	96959	50
11	17680	98425	19395	98101	21104	97748	22807	97365	24503	96952	49
12	17708	98420	19423	98096	21132	97742	22835	97358	24531	96945	48
13	17737	98414	19452	98090	21161	97735	22863	97351	24559	96937	47
14	17766	98409	19481	98084	21189	97729	22892	97345	24587	96930	46
15	17794	98404	19509	98079	21218	97723	22920	97338	24615	96923	45
16	17823	98399	19538	98073	21246	97717	22948	97331	24644	96916	44
17	17852	98394	19566	98067	21275	97711	22977	97325	24672	96909	43
18	17880	98389	19595	98061	21303	97705	23005	97318	24700	96902	42
19	17909	98383	19623	98056	21331	97698	23033	97311	24728	96894	41
20	17937	98378	19652	98050	21360	97692	23062	97304	24756	96887	40
21	17966	98373	19680	98044	21388	97686	23090	97298	24784	96880	39
22	17995	98368	19709	98039	21417	97680	23118	97291	24813	96873	38
23	18023	98362	19737	98033	21445	97673	23146	97284	24841	96866	37
24	18052	98357	19766	98027	21474	97667	23175	97278	24869	96858	36
25	18081	98352	19794	98021	21502	97661	23203	97271	24897	96851	35
26	18109	98347	19823	98016	21530	97655	23231	97264	24925	96844	34
27	18138	98341	19851	98010	21559	97648	23260	97257	24953	96837	33
28	18166	98336	19880	98004	21587	97642	23288	97251	24982	96829	32
29	18195	98331	19908	97998	21616	97636	23316	97244	25010	96822	31
30	18224	98325	19937	97992	21644	97630	23345	97237	25038	96815	30
31	18252	98320	19965	97987	21672	97623	23373	97230	25066	96807	29
32	18281	98315	19994	97981	21701	97617	23401	97223	25094	96800	28
33	18309	98310	20022	97975	21729	97611	23429	97217	25122	96793	27
34	18338	98304	20051	97969	21758	97604	23458	97210	25151	96786	26
35	18367	98299	20079	97963	21786	97598	23486	97203	25179	96778	25
36	18395	98294	20108	97958	21814	97592	23514	97196	25207	96771	24
37	18424	98288	20136	97952	21843	97585	23542	97189	25235	96764	23
38	18452	98283	20165	97946	21871	97579	23571	97182	25263	96756	22
39	18481	98277	20193	97940	21899	97573	23599	97176	25291	96749	21
30	18509	98272	20222	97934	21928	97566	23627	97169	25320	96742	20
41	18538	98267	20250	97928	21956	97560	23656	97162	25348	96734	19
42	18567	98261	20279	97922	21985	97553	23684	97155	25376	96727	18
43	18595	98256	20307	97916	22013	97547	23712	97148	25404	96719	17
44	18624	98250	20336	97910	22041	97541	23740	97141	25432	96712	16
45	18652	98245	20364	97905	22070	97534	23769	97134	25460	96705	15
46	18681	98240	20393	97899	22098	97528	23797	97127	25488	96697	14
47	18710	98234	20421	97893	22126	97521	23825	97120	25516	96690	13
48	18738	98229	20450	97887	22155	97515	23853	97113	25545	96682	12
49	18767	98223	20478	97881	22183	97508	23882	97106	25573	96675	11
50	18795	98218	20507	97875	22212	97502	23910	97100	25601	96667	10
51	18824	98212	20535	97869	22240	97496	23938	97093	25629	96660	9
52	18852	98207	20563	97863	22268	97489	23966	97086	25657	96653	8
53	18881	98201	20592	97857	22297	97483	23995	97079	25685	96645	7
54	18910	98196	20620	97851	22325	97476	24023	97072	25713	96638	6
55	18938	98190	20649	97845	22353	97470	24051	97065	25741	96630	5
56	18967	98185	20677	97839	22382	97463	24079	97058	25769	96623	4
57	18995	98179	20706	97833	22410	97457	24108	97051	25798	96615	3
58	19024	98174	20734	97827	22438	97450	24136	97044	25826	96608	2
59	19052	98168	20763	97821	22467	97444	24164	97037	25854	96600	1
M	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.		M
	79 Deg.		78 Deg.		77 Deg.		76 Deg.		75		

	15 Deg.		16 Deg.		17 Deg.		18 Deg.		19 Deg.		
M	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	S. C.	M
0	25882	96593	27564	96126	29237	95630	30902	95106	32557	94552	60
1	25910	96585	27592	96118	29265	95622	30929	95097	32584	94542	59
2	25938	96578	27620	96110	29293	95613	30957	95088	32612	94533	58
3	25966	96570	27648	96102	29321	95605	30985	95079	32639	94523	57
4	25994	96562	27676	96094	29348	95596	31012	95070	32667	94514	56
5	26022	96555	27704	96086	29376	95588	31040	95061	32694	94504	55
6	26050	96547	27731	96078	29404	95579	31068	95052	32722	94495	54
7	26079	96540	27759	96070	29432	95571	31095	95043	32749	94485	53
8	26107	96532	27787	96062	29460	95562	31123	95033	32777	94476	52
9	26135	96524	27815	96054	29487	95554	31151	95024	32804	94466	51
10	26163	96517	27843	96046	29515	95545	31178	95015	32832	94457	50
11	26191	96509	27871	96037	29543	95536	31206	95006	32859	94447	49
12	26219	96502	27899	96029	29571	95528	31233	94997	32887	94438	48
13	26247	96494	27927	96021	29599	95519	31261	94988	32914	94428	47
14	26275	96486	27955	96013	29626	95511	31289	94979	32942	94418	46
15	26303	96479	27983	96005	29654	95502	31316	94970	32969	94409	45
16	26331	96471	28011	95997	29682	95493	31344	94961	32997	94399	44
17	26359	96463	28039	95989	29710	95485	31372	94952	33024	94390	43
18	26387	96456	28067	95981	29737	95476	31399	94943	33051	94380	42
19	26415	96448	28095	95972	29765	95467	31427	94933	33079	94370	41
20	26443	96440	28123	95964	29793	95459	31454	94924	33106	94361	40
21	26471	96433	28150	95956	29821	95450	31482	94915	33134	94351	39
22	26500	96425	28178	95948	29849	95441	31510	94906	33161	94342	38
23	26528	96417	28206	95940	29876	95433	31537	94897	33189	94332	37
24	26556	96410	28234	95931	29904	95424	31565	94888	33216	94322	36
25	26584	96402	28262	95923	29932	95415	31593	94878	33244	94313	35
26	26612	96394	28290	95915	29960	95407	31620	94869	33271	94303	34
27	26640	96386	28318	95907	29987	95398	31648	94860	33298	94293	33
28	26668	96379	28346	95898	30015	95389	31675	94851	33326	94284	32
29	26696	96371	28374	95890	30043	95380	31703	94842	33353	94274	31
30	26724	96363	28402	95882	30071	95372	31730	94832	33381	94264	30
31	26752	96355	28429	95874	30098	95363	31758	94823	33408	94254	29
32	26780	96347	28457	95865	30126	95354	31786	94814	33436	94245	28
33	26808	96340	28485	95857	30154	95345	31813	94805	33463	94235	27
34	26836	96332	28513	95849	30182	95337	31841	94795	33490	94225	26
35	26864	96324	28541	95841	30209	95328	31868	94786	33518	94215	25
36	26892	96316	28569	95832	30237	95319	31896	94777	33545	94206	24
37	26920	96308	28597	95824	30265	95310	31923	94768	33573	94196	23
38	26948	96301	28625	95816	30292	95301	31951	94758	33600	94186	22
39	26976	96293	28652	95807	30320	95293	31979	94749	33627	94176	21
40	27004	96285	28680	95799	30348	95284	32006	94740	33655	94167	20
41	27032	96277	28708	95791	30376	95275	32034	94730	33682	94157	19
42	27060	96269	28736	95782	30403	95266	32051	94721	33710	94147	18
43	27088	96261	28764	95774	30431	95257	32089	94712	33737	94137	17
44	27116	96253	28792	95766	30459	95248	32116	94702	33764	94127	16
45	27144	96246	28820	95757	30486	95240	32144	94693	33792	94118	15
46	27172	96238	28847	95749	30514	95231	32171	94684	33819	94108	14
47	27200	96230	28875	95740	30542	95222	32199	94674	33846	94098	13
48	27228	96222	28903	95732	30570	95213	32227	94665	33874	94088	12
49	27256	96214	28931	95724	30597	95204	32254	94656	33901	94078	11
50	27284	96206	28959	95715	30625	95195	32282	94646	33929	94068	10
51	27312	96198	28987	95707	30653	95186	32309	94637	33956	94058	9
52	27340	96190	29015	95698	30680	95177	32337	94627	33983	94049	8
53	27368	96182	29042	95690	30708	95168	32364	94618	34011	94039	7
54	27396	96174	29070	95681	30736	95159	32392	94609	34038	94029	6
55	27424	96166	29098	95673	30763	95150	32419	94599	34065	94019	5
56	27452	96158	29126	95664	30791	95142	32447	94590	34093	94009	4
57	27480	96150	29154	95656	30819	95133	32474	94580	34120	93999	3
58	27508	96142	29182	95647	30846	95124	32502	94571	34147	93989	2
59	27536	96134	29209	95639	30874	95115	32529	94561	34175	93979	1
M	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	M
	74 Deg.		78 Deg.		72 Deg.		71 Deg.		70 Deg.		

M	20 Deg.		21 Deg.		22 Deg.		23 Deg.		24 Deg.		M
	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	
0	34202	93969	35837	93358	37461	92718	39073	92050	40674	91355	60
1	34229	93959	35864	93348	37488	92707	39100	92039	40700	91343	59
2	34257	93949	35891	93337	37515	92697	39127	92028	40727	91331	58
3	34284	93939	35918	93327	37542	92686	39153	92016	40753	91319	57
4	34311	93929	35945	93316	37569	92675	39180	92005	40780	91307	56
5	34339	93919	35973	93306	37595	92664	39207	91994	40806	91295	55
6	34366	93909	36000	93295	37622	92653	39234	91982	40833	91283	54
7	34393	93899	36027	93285	37649	92642	39260	91971	40860	91272	53
8	34421	93889	36054	93274	37676	92631	39287	91959	40886	91260	52
9	34448	93879	36081	93264	37703	92620	39314	91948	40913	91248	51
10	34475	93869	36108	93253	37730	92609	39341	91936	40939	91236	50
11	34503	93859	36135	93243	37757	92598	39367	91925	40966	91224	49
12	34530	93849	36162	93232	37784	92587	39394	91914	40992	91212	48
13	34557	93839	36190	93222	37811	92576	39421	91902	41019	91200	47
14	34584	93829	36217	93211	37838	92565	39448	91891	41045	91188	46
15	34612	93819	36244	93201	37865	92554	39474	91879	41072	91176	45
16	34639	93809	36271	93190	37892	92543	39501	91868	41098	91164	44
17	34666	93799	36298	93180	37919	92532	39528	91856	41125	91152	43
18	34694	93789	36325	93169	37946	92521	39555	91845	41151	91140	42
19	34721	93779	36352	93159	37973	92510	39581	91833	41178	91128	41
20	34748	93769	36379	93148	37999	92499	39608	91822	41204	91116	40
21	34775	93759	36406	93137	38026	92488	39635	91810	41231	91104	39
22	34803	93748	36434	93127	38053	92477	39661	91799	41257	91092	38
23	34830	93738	36461	93116	38080	92466	39688	91787	41284	91080	37
24	34857	93728	36488	93106	38107	92455	39715	91775	41310	91068	36
25	34884	93718	36515	93095	38134	92444	39741	91764	41337	91056	35
26	34912	93708	36542	93084	38161	92432	39768	91752	41363	91044	34
27	34939	93698	36569	93074	38188	92421	39795	91741	41390	91032	33
28	34966	93688	36596	93063	38215	92410	39822	91729	41416	91020	32
29	34993	93677	36623	93052	38241	92399	39848	91718	41443	91008	31
30	35021	93667	36650	93042	38268	92388	39875	91706	41469	90996	30
31	35048	93657	36677	93031	38295	92377	39902	91694	41496	90984	29
32	35075	93647	36704	93020	38322	92366	39928	91683	41522	90972	28
33	35102	93637	36731	93010	38349	92355	39955	91671	41549	90960	27
34	35130	93626	36758	92999	38376	92343	39982	91660	41575	90948	26
35	35157	93616	36785	92988	38403	92332	40008	91648	41602	90936	25
36	35183	93606	36812	92978	38430	92321	40035	91636	41628	90924	24
37	35211	93596	36839	92967	38456	92310	40062	91625	41655	90911	23
38	35239	93585	36867	92956	38483	92299	40088	91613	41681	90899	22
39	35266	93575	36894	92945	38510	92287	40115	91601	41707	90887	21
40	35293	93565	36921	92935	38537	92276	40141	91590	41734	90875	20
41	35320	93555	36948	92924	38564	92265	40168	91578	41760	90863	19
42	35347	93544	36975	92913	38591	92254	40195	91566	41787	90851	18
43	35375	93534	37002	92902	38617	92243	40221	91555	41813	90839	17
44	35402	93524	37029	92892	38644	92231	40248	91543	41840	90826	16
45	35429	93514	37056	92881	38671	92220	40275	91531	41866	90814	15
46	35456	93503	37083	92870	38698	92209	40301	91519	41892	90802	14
47	35484	93493	37110	92859	38725	92198	40328	91508	41919	90790	13
48	35511	93483	37137	92849	38752	92186	40355	91496	41945	90778	12
49	35538	93472	37164	92838	38778	92175	40381	91484	41972	90766	11
50	35565	93462	37191	92827	38805	92164	40408	91472	41998	90753	10
51	35592	93451	37218	92816	38832	92152	40434	91461	42024	90741	9
52	35619	93441	37245	92805	38859	92141	40461	91449	42051	90729	8
53	35647	93431	37272	92794	38886	92130	40488	91437	42077	90717	7
54	35674	93420	37299	92784	38912	92119	40514	91425	42104	90704	6
55	35701	93410	37326	92773	38939	92107	40541	91414	42130	90692	5
56	35728	93400	37353	92762	38966	92096	40567	91402	42156	90680	4
57	35755	93389	37380	92751	38993	92085	40594	91390	42183	90668	3
58	35782	93379	37407	92740	39020	92073	40621	91378	42209	90655	2
59	35810	93368	37434	92729	39046	92062	40647	91366	42235	90643	1
M	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S	
	69 Deg.		68 Deg.		67 Deg		66 Deg.		65 Deg		

	25 Deg.		26 Deg.		27 Deg.		28 Deg.		29 Deg.		
M	S	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	M
0	42262	90631	43837	89879	45399	89101	46947	88295	48481	87462	60
1	42288	90618	43863	89867	45425	89087	46973	88281	48506	87448	59
2	42315	90606	43889	89854	45451	89074	46999	88267	48532	87434	58
3	42341	90594	43916	89841	45477	89061	47024	88254	48557	87420	57
4	42367	90582	43942	89828	45503	89048	47050	88240	48583	87406	56
5	42394	90569	43968	89816	45529	89035	47076	88226	48608	87391	55
6	42420	90557	43994	89803	45554	89021	47101	88213	48634	87377	54
7	42446	90545	44020	89790	45580	89008	47127	88199	48659	87363	53
8	42473	90532	44046	89777	45606	88995	47153	88185	48684	87349	52
9	42499	90520	44072	89764	45632	88981	47178	88172	48710	87335	51
10	42525	90507	44098	89752	45658	88968	47204	88158	48735	87321	50
11	42552	90495	44124	89739	45684	88955	47229	88144	48761	87306	49
12	42578	90483	44151	89726	45710	88942	47255	88130	48786	87292	48
13	42604	90470	44177	89713	45736	88928	47281	88117	48811	87278	47
14	42631	90458	44203	89700	45762	88915	47306	88103	48837	87264	46
15	42657	90446	44229	89687	45787	88902	47332	88089	48862	87250	45
16	42683	90433	44255	89674	45813	88888	47358	88075	48888	87235	44
17	42709	90421	44281	89662	45839	88875	47383	88062	48913	87221	43
18	42736	90408	44307	89649	45865	88862	47409	88048	48938	87207	42
19	42762	90396	44333	89636	45891	88848	47434	88034	48964	87193	41
20	42788	90383	44359	89623	45917	88835	47460	88020	48989	87178	40
21	42815	90371	44385	89610	45942	88822	47486	88006	49014	87164	39
22	42841	90358	44411	89597	45968	88808	47511	87993	49040	87150	38
23	42867	90346	44437	89584	45994	88795	47537	87979	49065	87136	37
24	42894	90334	44464	89571	46020	88782	47562	87965	49090	87121	36
25	42920	90321	44490	89558	46046	88768	47588	87951	49116	87107	35
26	42946	90309	44516	89545	46072	88755	47614	87937	49141	87093	34
27	42972	90296	44542	89532	46097	88741	47639	87923	49166	87079	33
28	42999	90284	44568	89519	46123	88728	47665	87909	49192	87064	32
29	43025	90271	44594	89506	46149	88715	47690	87896	49217	87050	31
30	43051	90259	44620	89493	46175	88701	47716	87882	49242	87036	30
31	43077	90246	44646	89480	46201	88688	47741	87868	49268	87021	29
32	43104	90233	44672	89467	46226	88674	47767	87854	49293	87007	28
33	43130	90221	44698	89454	46252	88661	47793	87840	49318	86993	27
34	43156	90208	44724	89441	46278	88647	47818	87826	49344	86978	26
35	43182	90196	44750	89428	46304	88634	47844	87812	49369	86964	25
36	43209	90183	44776	89415	46330	88620	47869	87798	49394	86949	24
37	43235	90171	44802	89402	46355	88607	47895	87784	49419	86935	23
38	43261	90158	44828	89389	46381	88593	47920	87770	49445	86921	22
39	43287	90146	44854	89376	46407	88580	47946	87756	49470	86906	21
40	43313	90133	44880	89363	46433	88566	47971	87743	49495	86892	20
41	43340	90120	44906	89350	46458	88553	47997	87729	49521	86878	19
42	43366	90108	44932	89337	46484	88539	48022	87715	49546	86863	18
43	43392	90095	44958	89324	46510	88526	48048	87701	49571	86849	17
44	43418	90082	44984	89311	46536	88512	48073	87687	49596	86834	16
45	43445	90070	45010	89298	46561	88499	48099	87673	49622	86820	15
46	43471	90057	45036	89285	46587	88485	48124	87659	49647	86805	14
47	43497	90045	45062	89272	46613	88472	48150	87645	49672	86791	13
48	43523	90032	45088	89259	46639	88458	48175	87631	49697	86777	12
49	43549	90019	45114	89245	46664	88445	48201	87617	49723	86762	11
50	43575	90007	45140	89232	46690	88431	48226	87603	49748	86748	10
51	43602	89994	45166	89219	46716	88417	48252	87589	49773	86733	9
52	43628	89981	45192	89206	46742	88404	48277	87575	49798	86719	8
53	43654	89968	45218	89193	46767	88390	48303	87561	49824	86704	7
54	43680	89956	45243	89180	46793	88377	48328	87546	49849	86690	6
55	43706	89943	45269	89167	46819	88363	48354	87532	49874	86675	5
56	43733	89930	45295	89153	46844	88349	48379	87518	49899	86661	4
57	43759	89918	45321	89140	46870	88336	48405	87504	49924	86646	3
58	43785	89905	45347	89127	46896	88322	48430	87490	49950	86632	2
59	43811	89892	45373	89114	46921	88308	48456	87476	49975	86617	1
M	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	M
	64 Deg.		63 Deg.		62 Deg.		61 Deg.		60 Deg.		

M	30 Deg.		31 Deg.		32 Deg.		33 Deg.		34 Deg.		M
	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S	S.	C. S.	
0	50000	86603	51504	85717	52992	84805	54464	83867	55919	82904	60
1	50025	86588	51529	85702	53017	84789	54488	83851	55943	82887	59
2	50050	86573	51554	85687	53041	84774	54513	83835	55968	82871	58
3	50076	86559	51579	85672	53066	84759	54537	83819	55992	82855	57
4	50101	86544	51604	85657	53091	84743	54561	83804	56016	82839	56
5	50126	86530	51628	85642	53115	84728	54586	83788	56040	82822	55
6	50151	86515	51653	85627	53140	84712	54610	83772	56064	82806	54
7	50176	86501	51678	85612	53164	84697	54635	83756	56088	82790	53
8	50201	86486	51703	85597	53189	84681	54659	83740	56112	82773	52
9	50227	86471	51728	85582	53214	84666	54683	83724	56136	82757	51
10	50252	86457	51753	85567	53238	84650	54708	83708	56160	82741	50
11	50277	86442	51778	85551	53263	84635	54732	83692	56184	82724	49
12	50302	86427	51803	85536	53288	84619	54756	83676	56208	82708	48
13	50327	86413	51828	85521	53312	84604	54781	83660	56232	82692	47
14	50352	86398	51852	85506	53337	84588	54805	83645	56256	82675	46
15	50377	86384	51877	85491	53361	84573	54829	83629	56280	82659	45
16	50403	86369	51902	85476	53386	84557	54854	83613	56305	82643	44
17	50428	86354	51927	85461	53411	84542	54878	83597	56329	82626	43
18	50453	86340	51952	85446	53435	84526	54902	83581	56353	82610	42
19	50478	86325	51977	85431	53460	84511	54927	83565	56377	82593	41
20	50503	86310	52002	85416	53484	84495	54951	83549	56401	82577	40
21	50528	86295	52026	85401	53509	84480	54975	83533	56425	82561	39
22	50553	86281	52051	85385	53534	84464	54999	83517	56449	82544	38
23	50578	86266	52076	85370	53558	84448	55024	83501	56473	82528	37
24	50603	86251	52101	85355	53583	84433	55048	83485	56497	82511	36
25	50628	86237	52126	85340	53607	84417	55072	83469	56521	82495	35
26	50654	86222	52151	85325	53632	84402	55097	83453	56545	82478	34
27	50679	86207	52175	85310	53656	84386	55121	83437	56569	82462	33
28	50704	86192	52200	85294	53681	84370	55145	83421	56593	82446	32
29	50729	86178	52225	85279	53705	84355	55169	83405	56617	82429	31
30	50754	86163	52250	85264	53730	84339	55194	83389	56641	82413	30
31	50779	86148	52275	85249	53754	84324	55218	83373	56665	82396	29
32	50804	86133	52299	85234	53779	84308	55242	83356	56689	82380	28
33	50829	86119	52324	85218	53804	84292	55266	83340	56713	82363	27
34	50854	86104	52349	85203	53828	84277	55291	83324	56736	82347	26
35	50879	86089	52374	85188	53853	84261	55315	83308	56760	82330	25
36	50904	86074	52399	85173	53877	84245	55339	83292	56784	82314	24
37	50929	86059	52423	85157	53902	84230	55363	83276	56808	82297	23
38	50954	86045	52448	85142	53926	84214	55388	83260	56832	82281	22
39	50979	86030	52473	85127	53951	84198	55412	83244	56856	82264	21
40	51004	86015	52498	85112	53975	84182	55436	83228	56880	82248	20
41	51029	86000	52522	85096	54000	84167	55460	83212	56904	82231	19
42	51054	85985	52547	85081	54024	84151	55484	83195	56928	82214	18
43	51079	85970	52572	85066	54049	84135	55509	83179	56952	82198	17
44	51104	85956	52597	85051	54073	84120	55533	83163	56976	82181	16
45	51129	85941	52621	85035	54097	84104	55557	83147	57000	82165	15
46	51154	85926	52646	85020	54122	84088	55581	83131	57024	82148	14
47	51179	85911	52671	85005	54146	84072	55605	83115	57047	82132	13
48	51204	85896	52696	84989	54171	84057	55630	83098	57071	82115	12
49	51229	85881	52720	84974	54195	84041	55654	83082	57095	82098	11
50	51254	85866	52745	84959	54220	84025	55678	83066	57119	82082	10
51	51279	85851	52770	84943	54244	84009	55702	83050	57143	82065	9
52	51304	85836	52794	84928	54269	83994	55726	83034	57167	82048	8
53	51329	85821	52819	84913	54293	83978	55750	83017	57191	82032	7
54	51354	85806	52844	84897	54317	83962	55775	83001	57215	82015	6
55	51379	85792	52869	84882	54342	83946	55799	82985	57238	81999	5
56	51404	85777	52893	84866	54366	83930	55823	82969	57262	81982	4
57	51429	85762	52918	84851	54391	83915	55847	82953	57286	81965	3
58	51454	85747	52943	84836	54415	83899	55871	82936	57310	81949	2
59	51479	85732	52967	84820	54440	83883	55895	82920	57334	81932	1
M	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	M
	59 Deg		58 Deg.		57 Deg.		56 Deg.		55 D		

	35 Deg.		36 Deg.		37 Deg.		38 Deg.		39 Deg.		
M	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	M
0	57358	81915	58779	80902	60182	79864	61566	78801	62932	77715	60
1	57381	81899	58802	80885	60205	79846	61589	78783	62955	77696	59
2	57405	81882	58826	80867	60228	79829	61612	78765	62977	77678	58
3	57429	81865	58849	80850	60251	79811	61635	78747	63000	77660	57
4	57453	81848	58873	80833	60274	79793	61658	78729	63022	77641	56
5	57477	81832	58896	80816	60298	79776	61681	78711	63045	77623	55
6	57501	81815	58920	80799	60321	79758	61704	78694	63068	77605	54
7	57524	81798	58943	80782	60344	79741	61726	78676	63090	77586	53
8	57548	81782	58967	80765	60367	79723	61749	78658	63113	77568	52
9	57572	81765	58990	80748	60390	79706	61772	78640	63135	77550	51
10	57596	81748	59014	80730	60414	79688	61795	78622	63158	77531	50
11	57619	81731	59037	80713	60437	79671	61818	78604	63180	77513	49
12	57643	81714	59061	80696	60460	79653	61841	78586	63203	77494	48
13	57667	81698	59084	80679	60483	79635	61864	78568	63225	77476	47
14	57691	81681	59108	80662	60506	79618	61887	78550	63248	77458	46
15	57715	81664	59131	80644	60529	79600	61909	78532	63271	77439	45
16	57738	81647	59154	80627	60553	79583	61932	78514	63293	77421	44
17	57762	81631	59178	80610	60576	79565	61955	78496	63316	77402	43
18	57786	81614	59201	80593	60599	79547	61978	78478	63338	77384	42
19	57810	81597	59225	80576	60622	79530	62001	78460	63361	77366	41
20	57833	81580	59248	80558	60645	79512	62024	78442	63383	77347	40
21	57857	81563	59272	80541	60668	79494	62046	78424	63406	77329	39
22	57881	81546	59295	80524	60691	79477	62069	78405	63428	77310	38
23	57904	81530	59318	80507	60714	79459	62092	78387	63451	77292	37
24	57928	81513	59342	80489	60738	79441	62115	78369	63473	77273	36
25	57952	81496	59365	80472	60761	79424	62138	78351	63496	77255	35
26	57976	81479	59389	80455	60784	79406	62160	78333	63518	77236	34
27	57999	81462	59412	80438	60807	79388	62183	78315	63540	77218	33
28	58023	81445	59436	80420	60830	79371	62206	78297	63563	77199	32
29	58047	81428	59459	80403	60853	79353	62229	78279	63585	77181	31
30	58070	81412	59482	80386	60876	79335	62251	78261	63608	77162	30
31	58094	81395	59506	80368	60899	79318	62274	78243	63030	77144	29
32	58118	81378	59529	80351	60922	79300	62297	78225	63653	77125	28
33	58141	81361	59552	80334	60945	79282	62320	78206	63675	77107	27
34	58165	81344	59576	80316	60968	79264	62342	78188	63698	77088	26
35	58189	81327	59599	80299	60991	79247	62365	78170	63720	77070	25
36	53212	81310	59622	80282	61015	79229	62388	78152	63742	77051	24
37	58236	81293	59646	80264	61038	79211	62411	78134	63765	77033	23
38	58260	81276	59669	80247	61061	79193	62433	78116	63787	77014	22
39	58283	81259	59693	80230	61084	79176	62456	78098	63810	76996	21
40	58307	81242	59716	80212	61107	79158	62479	78079	63832	76977	20
41	58330	81225	59739	80195	61130	79140	62502	78061	63854	76959	19
42	58354	81208	59763	80178	61153	79122	62524	78043	63877	76940	18
43	58378	81191	59786	80160	61176	79105	62547	78025	63899	76921	17
44	58401	81174	59809	80143	61199	79087	62570	78007	63922	76903	16
45	58425	81157	59832	80125	61222	79069	62592	77988	63944	76884	15
46	58449	81140	59856	80108	61245	79051	62615	77970	63966	76866	14
47	58472	81123	59879	80091	61268	79033	62638	77952	63989	76847	13
48	58496	81106	59902	80073	61291	79015	62660	77934	64011	76828	12
49	58519	81089	59926	80056	61314	78998	62683	77916	64033	76810	11
50	58543	81072	59949	80038	61337	78980	62706	77897	64056	76791	10
51	58567	81055	59972	80021	61360	78962	62728	77879	64078	76772	9
52	58590	81038	59995	80003	61383	78944	62751	77861	64100	76754	8
53	58614	81021	60019	79986	61406	78926	52774	77843	64123	76735	7
54	53637	81004	60042	79968	61429	78908	62796	77824	64145	76717	6
55	58661	80987	60065	79951	61451	78891	62819	77806	64167	76698	5
56	58684	80970	60089	79934	61474	78873	62842	77788	64190	76679	4
57	58708	80953	60112	79916	61497	78855	62864	77769	64212	76661	3
58	58731	80936	60135	79899	61520	78837	62887	77751	64234	76642	2
59	58755	80919	60158	79881	61543	78819	62909	77733	64256	76623	1
M	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	M
	54 Deg.		53 Deg.		52 Deg.		51 Deg.		50 Deg.		

	40 Deg		41 Deg.		42 Deg.		43 Deg.		44 Deg.		
M	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	M
0	64279	76604	65606	75471	66913	74314	68200	73135	69466	71934	60
1	64301	76586	65628	75452	66935	74295	68221	73116	69487	71914	59
2	64323	76567	65650	75433	66956	74276	68242	73096	69508	71894	58
3	64346	76548	65672	75414	66978	74256	68264	73076	69529	71873	57
4	64368	76530	65694	75395	66999	74237	68285	73056	69549	71853	56
5	64390	76511	65716	75375	67021	74217	68306	73036	69570	71833	55
6	64412	76492	65738	75356	67043	74198	68327	73016	69591	71813	54
7	64435	76473	65759	75337	67064	74178	68349	72996	69612	71792	53
8	64457	76455	65781	75318	67086	74159	68370	72976	69633	71772	52
9	64479	76436	65803	75299	67107	74139	68391	72957	69654	71752	51
10	64501	76417	65825	75280	67129	74120	68412	72937	69675	71732	50
11	64524	76398	65847	75261	67151	74100	68433	72917	69696	71711	49
12	64546	76380	65869	75241	67172	74080	68455	72897	69717	71691	48
13	64568	76361	65891	75222	67194	74061	68476	72877	69737	71671	47
14	64590	76342	65913	75203	67215	74041	68497	72857	69758	71650	46
15	64612	76323	65935	75184	67237	74022	68518	72837	69779	71630	45
16	64635	76304	65956	75165	67258	74002	68539	72817	69800	71610	44
17	64657	76286	65978	75146	67280	73983	68561	72797	69821	71590	43
18	64679	76267	66000	75126	67301	73963	68582	72777	69842	71569	42
19	64701	76248	66022	75107	67323	73944	68603	72757	69862	71549	41
20	64723	76229	66044	75088	67344	73924	68624	72737	69883	71529	40
21	64746	76210	66066	75069	67366	73904	68645	72717	69904	71508	39
22	64768	76192	66088	75050	67387	73885	68666	72697	69925	71488	38
23	64790	76173	66109	75030	67409	73865	68688	72677	69946	71468	37
24	64812	76154	66131	75011	67430	73846	68709	72657	69966	71447	36
25	64834	76135	66153	74992	67452	73826	68730	72637	69987	71427	35
26	64856	76116	66175	74973	67473	73806	68751	72617	70008	71407	34
27	64878	76097	66197	74953	67495	73787	68772	72597	70029	71386	33
28	64901	76078	66218	74934	67516	73767	68793	72577	70049	71366	32
29	64923	76059	66240	74915	67538	73747	68814	72557	70070	71345	31
30	64945	76041	66262	74896	67559	73728	68835	72537	70091	71325	30
31	64967	76022	66284	74876	67580	73708	68857	72517	70112	71305	29
32	64989	76003	66306	74857	67602	73688	68878	72497	70132	71284	28
33	65011	75984	66327	74838	67623	73669	68899	72477	70153	71264	27
34	65033	75965	66349	74818	67645	73649	68920	72457	70174	71243	26
35	65055	75946	66371	74799	67666	73629	68941	72437	70195	71223	25
36	65077	75927	66393	74780	67688	73610	68962	72417	70215	71203	24
37	65099	75908	66414	74760	67709	73590	68983	72397	70236	71182	23
38	65122	75889	66436	74741	67730	73570	69004	72377	70257	71162	22
39	65144	75870	66458	74722	67752	73551	69025	72357	70277	71141	21
40	65166	75851	66480	74703	67773	73531	69046	72337	70298	71121	20
41	65188	75832	66501	74683	67795	73511	69067	72317	70319	71100	19
42	65210	75813	66523	74664	67816	73491	69088	72297	70339	71080	18
43	65232	75794	66545	74644	67837	73472	69109	72277	70360	71059	17
44	65254	75775	66566	74625	67859	73452	69130	72257	70381	71039	16
45	65276	75756	66588	74606	67880	73432	69151	72236	70401	71019	15
46	65298	75738	66610	74586	67901	73412	69172	72216	70422	70998	14
47	65320	75719	66632	74567	67923	73393	69193	72196	70443	70978	13
48	65342	75699	66653	74548	67944	73373	69214	72176	70463	70957	12
49	65364	75680	66675	74528	67965	73353	69235	72156	70484	70937	11
50	65386	75661	66697	74509	67987	73333	69256	72136	70505	70916	10
51	65408	75642	66718	74489	68008	73314	69277	72116	70525	70896	9
52	65430	75623	66740	74470	68029	73294	69298	72095	70546	70875	8
53	65452	75604	66762	74451	68051	73274	69319	72075	70567	70855	7
54	65474	75585	66783	74431	68072	73254	69340	72055	70587	70834	6
55	65496	75566	66805	74412	68093	73234	69361	72035	70608	70813	5
56	65518	75547	66827	74392	68115	73215	69382	72015	70628	70793	4
57	65540	75528	66848	74373	68136	73195	69403	71995	70649	70772	3
58	65562	75509	66870	74353	68157	73175	69424	71974	70670	70752	2
59	65584	75490	66891	74334	68179	73155	69445	71954	70690	70731	1
60	65606	75471	66913	74314	68200	73135	69466	71934	70711	70711	0
M	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	C. S.	S.	M
	49 Deg.		48 Deg.		47 Deg.		46 Deg.		45 Deg.		

Distance.	¼ Deg.		½ Deg.		¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep	
1	1.00	0.00	1.00	0.01	1.00	0.01	1
2	2.00	0.01	2.00	0.02	2.00	0.03	2
3	3.00	0.01	3.00	0.03	3.00	0.04	3
4	4.00	0.02	4.00	0.03	4.00	0.05	4
5	5.00	0.02	5.00	0.04	5.00	0.07	5
6	6.00	0.03	6.00	0.05	6.00	0.08	6
7	7.00	0.03	7.00	0.06	7.00	0.09	7
8	8.00	0.03	8.00	0.07	8.00	0.10	8
9	9.00	0.04	9.00	0.08	9.00	0.12	9
10	10.00	0.04	10.00	0.09	10.00	0.13	10
11	11.00	0.05	11.00	0.10	11.00	0.14	11
12	12.00	0.05	12.00	0.10	12.00	0.16	12
13	13.00	0.06	13.00	0.11	13.00	0.17	13
14	14.00	0.06	14.00	0.12	14.00	0.18	14
15	15.00	0.07	15.00	0.13	15.00	0.20	15
16	16.00	0.07	16.00	0.14	16.00	0.21	16
17	17.00	0.07	17.00	0.15	17.00	0.22	17
18	18.00	0.08	18.00	0.16	18.00	0.24	18
19	19.00	0.08	19.00	0.17	19.00	0.25	19
20	20.00	0.09	20.00	0.17	20.00	0.26	20
21	21.00	0.09	21.00	0.18	21.00	0.27	21
22	22.00	0.10	22.00	0.19	22.00	0.29	22
23	23.00	0.10	23.00	0.20	23.00	0.30	23
24	24.00	0.10	24.00	0.21	24.00	0.31	24
25	25.00	0.11	25.00	0.22	25.00	0.33	25
26	26.00	0.11	26.00	0.23	26.00	0.34	26
27	27.00	0.12	27.00	0.24	27.00	0.35	27
28	28.00	0.12	28.00	0.24	28.00	0.37	28
29	29.00	0.13	29.00	0.25	29.00	0.38	29
30	30.00	0.13	30.00	0.26	30.00	0.39	30
31	31.00	0.14	31.00	0.27	31.00	0.41	31
32	32.00	0.14	32.00	0.28	32.00	0.42	32
33	33.00	0.14	33.00	0.29	33.00	0.43	33
34	34.00	0.15	34.00	0.30	34.00	0.45	34
35	35.00	0.15	35.00	0.31	35.00	0.46	35
36	36.00	0.16	36.00	0.31	36.00	0.47	36
37	37.00	0.16	37.00	0.32	37.00	0.48	37
38	38.00	0.17	38.00	0.33	38.00	0.50	38
39	39.00	0.17	39.00	0.34	39.00	0.51	39
40	40.00	0.17	40.00	0.35	40.00	0.52	40
41	41.00	0.18	41.00	0.36	41.00	0.54	41
42	42.00	0.18	42.00	0.37	42.00	0.55	42
43	43.00	0.19	43.00	0.38	43.00	0.56	43
44	44.00	0.19	44.00	0.38	44.00	0.58	44
45	45.00	0.20	45.00	0.39	45.00	0.59	45
46	46.00	0.20	46.00	0.40	46.00	0.60	46
47	47.00	0.21	47.00	0.41	47.00	0.62	47
48	48.00	0.21	48.00	0.42	48.00	0.63	48
49	49.00	0.21	49.00	0.43	49.00	0.64	49
50	50.00	0.22	50.00	0.44	50.00	0.65	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	89¾ Deg.		89½ Deg.		89¼ Deg.		

Distance.	¼ Deg.		½ Deg.		¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	51.00	0.22	51.00	0.45	51.00	0.67	51
52	52.00	0.23	52.00	0.45	52.00	0.68	52
53	53.00	0.23	53.00	0.46	53.00	0.69	53
54	54.00	0.24	54.00	0.47	54.00	0.71	54
55	55.00	0.24	55.00	0.48	55.00	0.72	55
56	56.00	0.24	56.00	0.49	56.00	0.73	56
57	57.00	0.25	57.00	0.50	57.00	0.75	57
58	58.00	0.25	58.00	0.51	57.99	0.76	58
59	59.00	0.26	59.00	0.51	58.99	0.77	59
60	60.00	0.26	60.00	0.52	59.99	0.79	60
61	61.00	0.27	61.00	0.53	60.99	0.80	61
62	62.00	0.27	62.00	0.54	61.99	0.81	62
63	63.00	0.27	63.00	0.55	62.99	0.82	63
64	64.00	0.28	64.00	0.56	63.99	0.84	64
65	65.00	0.28	65.00	0.57	64.99	0.85	65
66	66.00	0.29	66.00	0.58	65.99	0.86	66
67	67.00	0.29	67.00	0.58	66.99	0.88	67
68	68.00	0.30	68.00	0.59	67.99	0.89	68
69	69.00	0.30	69.00	0.60	68.99	0.90	69
70	70.00	0.31	70.00	0.61	69.99	0.92	70
71	71.00	0.31	71.00	0.62	70.99	0.93	71
72	72.00	0.31	72.00	0.63	71.99	0.94	72
73	73.00	0.32	73.00	0.64	72.99	0.96	73
74	74.00	0.32	74.00	0.65	73.99	0.97	74
75	75.00	0.33	75.00	0.65	74.99	0.98	75
76	76.00	0.33	76.00	0.66	75.99	0.99	76
77	77.00	0.34	77.00	0.67	76.99	1.01	77
78	78.00	0.34	78.00	0.68	77.99	1.02	78
79	79.00	0.34	79.00	0.69	78.99	1.03	79
80	80.00	0.35	80.00	0.70	79.99	1.05	80
81	81.00	0.35	81.00	0.71	80.99	1.06	81
82	82.00	0.36	82.00	0.72	81.99	1.07	82
83	83.00	0.36	83.00	0.72	82.99	1.09	83
84	84.00	0.37	84.00	0.73	83.99	1.10	84
85	85.00	0.37	85.00	0.74	84.99	1.11	85
86	86.00	0.38	86.00	0.75	85.99	1.13	86
87	87.00	0.38	87.00	0.76	86.99	1.14	87
88	88.00	0.38	88.00	0.77	87.99	1.15	88
89	89.00	0.39	89.00	0.78	88.99	1.16	89
90	90.00	0.39	90.00	0.79	89.99	1.18	90
91	91.00	0.40	91.00	0.79	90.99	1.19	91
92	92.00	0.40	92.00	0.80	91.99	1.20	92
93	93.00	0.41	93.00	0.81	92.99	1.22	93
94	94.00	0.41	94.00	0.82	93.99	1.23	94
95	95.00	0.41	95.00	0.83	94.99	1.24	95
96	96.00	0.42	96.00	0.84	95.99	1.26	96
97	97.00	0.42	97.00	0.85	96.99	1.27	97
98	98.00	0.43	98.00	0.86	97.99	1.28	98
99	99.00	0.43	99.00	0.86	98.99	1.30	99
100	100.00	0.44	100.00	0.87	99.99	1.31	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	89¾ Deg.		89½ Deg.		89¼ Deg.		

Distance.	1 Deg.		1¼ Deg.		1½ Deg.		1¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep	Lat.	Dep.	
1	1.00	0.02	1.00	0.02	1.00	[illegible]	1.00	0.03	1
2	2.00	0.03	2.00	0.04	2.00	[illegible]	2.00	0.06	2
3	3.00	0.05	3.00	0.07	3.00	[illegible]	3.00	0.09	3
4	4.00	0.07	4.00	0.09	4.00	0.10	4.00	0.12	4
5	5.00	0.09	5.00	0.11	5.00	0.13	5.00	0.15	5
6	6.00	0.10	6.00	0.13	6.00	0.16	6.00	0.18	6
7	7.00	0.12	7.00	0.15	7.00	0.18	7.00	0.21	7
8	8.00	0.14	8.00	0.17	8.00	0.21	8.00	0.25	8
9	9.00	0.16	9.00	0.20	9.00	0.24	9.00	0.28	9
10	10.00	0.17	10.00	0.22	10.00	0.26	10.00	0.31	10
11	11.00	0.19	11.00	0.24	11.00	0.28	10.99	0.34	11
12	12.00	0.21	12.00	0.26	12.00	0.31	11.99	0.37	12
13	13.00	0.23	13.00	0.28	13.00	0.34	12.99	0.40	13
14	14.00	0.24	14.00	0.31	14.00	0.37	13.99	0.43	14
15	15.00	0.26	15.00	0.33	14.99	0.39	14.99	0.46	15
16	16.00	0.28	16.00	0.35	15.99	0.42	15.99	0.49	16
17	17.00	0.30	17.00	0.37	16.99	0.45	16.99	0.52	17
18	18.00	0.31	18.00	0.39	17.99	0.47	17.99	0.55	18
19	19.00	0.33	19.00	0.41	18.99	0.50	18.99	0.58	19
20	20.00	0.35	20.00	0.44	19.99	0.52	19.99	0.61	20
21	21.00	0.37	21.00	0.46	20.99	0.55	20.99	0.64	21
22	22.00	0.38	21.99	0.48	21.99	0.58	21.99	0.67	22
23	23.00	0.40	22.99	0.50	22.99	0.60	22.99	0.70	23
24	24.00	0.42	23.99	0.52	23.99	0.63	23.99	0.73	24
25	25.00	0.44	24.99	0.55	24.99	0.65	24.99	0.76	25
26	26.00	0.45	25.99	0.57	25.99	0.68	25.99	0.79	26
27	27.00	0.47	26.99	0.59	26.99	0.71	26.99	0.83	27
28	28.00	0.49	27.99	0.61	27.99	0.73	27.99	0.86	28
29	29.00	0.51	28.99	0.63	28.99	0.76	28.99	0.89	29
30	30.00	0.52	29.99	0.65	29.99	0.79	29.99	0.92	30
31	31.00	0.54	30.99	0.68	20.99	0.81	30.99	0.95	31
32	32.00	0.56	31.99	0.70	31.99	0.84	31.99	0.98	32
33	32.99	0.58	32.99	0.72	32.99	0.86	32.98	1.01	33
34	33.99	0.59	33.99	0.74	33.99	0.89	33.98	1.04	34
35	34.99	0.61	34.99	0.76	34.99	0.92	34.98	1.07	35
36	35.99	0.63	35.99	0.79	35.99	0.94	35.98	1.10	36
37	36.99	0.65	36.99	0.81	36.99	0.97	36.98	1.13	37
38	37.99	0.66	37.99	0.83	37.99	0.99	37.98	1.16	38
39	38.99	0.68	38.99	0.85	38.99	1.02	38.98	1.19	39
40	39.99	0.70	39.99	0.87	39.99	1.05	39.98	1.22	40
41	40.99	0.72	40.99	0.89	40.99	1.07	40.98	1.25	41
42	41.99	0.73	41.99	0.92	41.99	1.10	41.98	1.28	42
43	42.99	0.75	42.99	0.94	42.99	1.13	42.98	1.31	43
44	43.99	0.77	43.99	0.96	43.99	1.15	43.98	1.34	44
45	44.99	0.79	44.99	0.98	44.99	1.18	44.98	1.37	45
46	45.99	0.80	45.99	1.00	45.99	1.20	45.98	1.40	46
47	46.99	0.82	46.99	1.03	46.99	1.23	46.98	1.44	47
48	47.99	0.84	47.99	1.05	47.98	1.26	47.98	1.47	48
49	48.99	0.86	48.99	1.07	48.98	1.28	48.98	1.50	49
50	49.99	0.87	49.99	1.09	49.98	1.31	49.98	1.53	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	89 Deg.		88¾ Deg.		88½ Deg.		88¼ Deg.		

Distance.	1 Deg.		1¼ Deg.		1½ Deg.		1¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	50.99	0.89	50.99	1.11	50.98	1.34	50.98	1.56	51
52	51 99	0.91	51.99	1.13	51.98	1.36	51.98	1.59	52
53	52 99	0.92	52.99	1.16	52.98	1.39	52.98	1.62	53
54	53 99	0.94	53.99	1.18	53.98	1.41	53.97	1 65	54
55	54 99	0.96	54.99	1.20	54.98	1.44	54.97	1.68	55
56	55.99	0.98	55.99	1.22	55.98	1.47	55.97	1.71	56
57	56.99	0.99	56.99	1.24	56 98	1.49	56.97	1.74	57
58	57.99	1.01	57.99	1.27	57.98	1.52	57.97	..77	58
59	58.99	1.03	58.99	1.29	58.98	1.54	58.97	1.80	59
60	59.99	1.05	59.99	1.31	59.98	1.57	59.97	1.83	60
61	60.99	1.06	60.99	1.33	60.98	1.60	60.97	1.86	61
62	61.99	1.08	61.99	1.35	61.98	1.62	61.97	1.89	62
63	62.99	1.10	62.99	1.37	62.98	1.65	62.97	1.92	63
64	63.99	1.12	63.98	1.40	63.98	1.68	63.97	1.95	64
65	64.99	1.13	64.98	1.42	64.98	1.70	64.97	1 99	65
66	65.99	1.15	65.98	1.44	65.98	1.73	65.97	2 02	66
67	66.99	1.17	66.98	1.46	66.98	1.75	66.97	2.05	67
68	67.99	1.19	67.98	1.48	67.98	1.78	67.97	2.08	68
69	68.99	1.20	68.98	1.51	68.98	1.81	68 97	2.11	69
70	69.99	1.22	69.98	1.53	69.98	1.83	69 97	2.14	70
71	70.99	1.24	70.98	1.55	70.98	1.86	70.97	2 17	71
72	71.99	1.26	71.98	1.57	71.98	1.88	71.97	2.20	72
73	72.99	1.27	72.98	1.59	72.97	1.91	72.97	2.23	73
74	73.99	1.29	73.98	1.61	73.97	1.94	73.97	2.26	74
75	74.99	1.31	74.98	1.64	74.97	1.96	74.97	2.29	75
76	75.99	1.33	75.98	1.66	75.97	1.99	75.96	2.32	76
77	76.99	1.34	76.98	1.68	76.97	2.02	76.96	2.35	77
78	77.99	1.36	77.98	1.70	77.97	2.04	77.96	2.38	78
79	78.99	1.38	78.98	1.72	78.97	2.07	78.96	2.41	79
80	79.99	1.40	79.98	1.75	79.97	2.09	79.96	2.44	80
81	80.99	1.41	80.98	1.77	80.97	2.12	80.96	2.47	81
82	81.99	1.43	81.98	1.79	81.97	2.15	81.96	2.50	82
83	82.99	1.45	82.98	1.81	82.97	2.17	82.96	2.53	83
84	83.99	1.47	83.98	1.83	83.97	2.20	83.96	2.57	84
85	84.99	1.48	84.98	1.85	84.97	2.23	84.96	2.60	85
86	85.99	1.50	85.98	1.88	85.97	2.25	85.96	2.63	86
87	86.99	1.52	86.98	1.90	86.97	2.28	86.96	2.66	87
88	87.99	1.54	87.98	1.92	87.97	2.30	87.96	2.69	88
89	88.99	1.55	88.98	1.94	88.97	2.33	88.96	2.72	89
90	89.99	1.57	89.98	1.96	89.97	2.36	89.96	2.75	90
91	90.99	1.59	90.98	1.99	90.97	2.38	90.96	2.78	91
92	91.99	1.61	91 98	2:01	91.97	2.41	91.96	2.81	92
93	92.99	1.62	92.98	2.03	92.97	2.43	92.96	2.84	93
94	93.99	1.64	93.98	2.05	93.97	2.46	93.96	2.87	94
95	94.99	1.66	94.98	2.07	94.97	2.49	94.96	2.90	95
96	95 99	1.68	95.98	2.09	95.97	2.51	95.96	2.94	96
97	96 99	1.69	96.98	2.12	96.97	2.54	96.95	2.96	97
98	97.99	1.71	97.98	2.14	97.97	2.57	97.95	2.99	98
99	98.98	1.73	98.98	2.16	98.97	2.59	98.95	3.02	99
100	99.98	1.75	99.98	2.18	99.97	2.62	99.95	3.05	100
Distance.	Dep.	Lat.	Dep	Lat.	Dep	Lat.	Dep.	Lat.	Distance.
	89 Deg.		88¾ Deg.		88½ Deg.		88¼ Deg.		

Distance.	2 Deg.		2¼ Deg.		2½ Deg.		2¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep	Lat.	Dep	
1	1.00	0.03	1.00	0.04	1.00	0.04	1.00	0.05	1
2	2.00	0.07	2.00	0.08	2.00	0.09	2.00	0.10	2
3	3.00	0.10	3.00	0.12	3.00	0.13	3.00	0.14	3
4	4.00	0.14	4.00	0.16	4.00	0.17	4.00	0.19	4
5	5.00	0.17	5.00	0.20	5.00	0.22	4.99	0.24	5
6	6.00	0.21	6.00	0.24	5.99	0.26	5.99	0.29	6
7	7.00	0.24	6.99	0.27	6.99	0.31	6.99	0.34	7
8	7.99	0.28	7.99	0.31	7.99	0.35	7.99	0.38	8
9	8.99	0.31	8.99	0.35	8.99	0.39	8.99	0.43	9
10	9.99	0.35	9.99	0.39	9.99	0.44	9.99	0.48	10
11	10.99	0.38	10.99	0.43	10.99	0.48	10.99	0.53	11
12	11.99	0.42	11.99	0.47	11.99	0.52	11.99	0.58	12
13	12.99	0.45	12.99	0.51	12.99	0.57	12.99	0.62	13
14	13.99	0.49	13.99	0.55	13.99	0.61	13.98	0.67	14
15	14.99	0.52	14.99	0.59	14.99	0.65	14.98	0.72	15
16	15.99	0.56	15.99	0.63	15.99	0.70	15.98	0.77	16
17	16.99	0.59	16.99	0.67	16.98	0.74	16.98	0.82	17
18	17.99	0.63	17.99	0.71	17.98	0.79	17.98	0.86	18
19	18.99	0.66	18.99	0.75	18.98	0.83	18.98	0.91	19
20	19.99	0.70	19.98	0.79	19.98	0.87	19.98	0.96	20
21	20.99	0.73	20.98	0.82	20.98	0.92	20.98	1.01	21
22	21.99	0.77	21.98	0.86	21.98	0.96	21.97	1.06	22
23	22.99	0.80	22.98	0.90	22.98	1.00	22.97	1.10	23
24	23.99	0.84	23.98	0.94	23.98	1.05	23.97	1.15	24
25	24.98	0.87	24.98	0.98	24.98	1.09	24.97	1.20	25
26	25.98	0.91	25.98	1.02	25.98	1.13	25.97	1.25	26
27	26.98	0.94	26.98	1.06	26.97	1.18	26.97	1.30	27
28	27.98	0.98	27.98	1.10	27.97	1.22	27.97	1.34	28
29	28.98	1.01	28.98	1.14	28.97	1.26	28.97	1.39	29
30	29.98	1.05	29.98	1.18	29.97	1.31	29.97	1.44	30
31	30.98	1.08	30.98	1.22	30.97	1.35	30.96	1.49	31
32	31.98	1.12	31.98	1.26	31.97	1.40	31.96	1.54	32
33	32.98	1.15	32.97	1.30	32.97	1.44	32.96	1.58	33
34	33.98	1.19	33.97	1.33	33.97	1.48	33.96	1.63	34
35	34.98	1.22	34.97	1.37	34.97	1.53	34.96	1.68	35
36	35.98	1.26	35.97	1.41	35.97	1.57	35.96	1.73	36
37	36.98	1.29	36.97	1.45	36.96	1.61	36.96	1.78	37
38	37.98	1.33	37.97	1.49	37.96	1.66	37.96	1.82	38
39	38.98	1.36	38.97	1.53	38.96	1.70	38.96	1.87	39
40	39.98	1.40	39.97	1.57	39.96	1.75	39.95	1.92	40
41	40.98	1.43	40.97	1.61	40.96	1.77	40.95	1.97	41
42	41.97	1.47	41.97	1.65	41.96	1.83	41.95	2.02	42
43	42.97	1.50	42.97	1.69	42.96	1.88	42.95	2.06	43
44	43.97	1.54	43.97	1.73	43.96	1.92	43.95	2.11	44
45	44.97	1.57	44.97	1.77	44.96	1.96	44.95	2.16	45
46	45.97	1.61	45.96	1.81	45.96	2.01	45.95	2.21	46
47	46.97	1.64	46.96	1.85	46.96	2.05	46.95	2.25	47
48	47.97	1.68	47.96	1.88	47.95	2.09	47.95	2.30	48
49	48.97	1.71	48.96	1.92	48.95	2.14	48.94	2.35	49
50	49.97	1.74	49.96	1.96	49.95	2.18	49.94	2.40	50
Distance.	Dep	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	88 Deg.		87¾ Deg.		87½ Deg.		87¼ Deg.		

Distance.	2 Deg.		2¼ Deg.		2½ Deg.		2¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	50.97	1.78	50.96	2.00	50.95	2.22	50.94	2.45	51
52	51.97	1.81	51.96	2.04	51.95	2.27	51.94	2.50	52
53	52.97	1.85	52.96	2.08	52.95	2.31	52.94	2.54	53
54	53.97	1.88	53.96	2.12	53.95	2.36	53.94	2.59	54
55	54.97	1.92	54.96	2.16	54.95	2.40	54.94	2.64	55
56	55.97	1.95	55.96	2.20	55.95	2.44	55.94	2.69	56
57	56.97	1.99	56.96	2.24	56.95	2.49	56.93	2.73	57
58	57.96	2.02	57.96	2.28	57.94	2.53	57.93	2.78	58
59	58.96	2.06	58.95	2.32	58.94	2.57	58.93	2.83	59
60	59.96	2.09	59.95	2.36	59.94	2.62	59.93	2.88	60
61	60.96	2.13	60.95	2.39	60.94	2.66	60.93	2.93	61
62	61.96	2.16	61.95	2.43	61.94	2.70	61.93	2.97	62
63	62.96	2.20	62.95	2.47	62.94	2.75	62.93	3.02	63
64	63.96	2.23	63.95	2.51	63.94	2.79	63.93	3.07	64
65	64.96	2.27	64.95	2.55	64.94	2.84	64.93	3.12	65
66	65.96	2.30	65.95	2.59	65.94	2.88	65.92	3.17	66
67	66.96	2.34	66.95	2.63	66.94	2.92	66.92	3.21	67
68	67.96	2.37	67.95	2.67	67.94	2.97	67.92	3.26	68
69	68.96	2.41	68.95	2.71	68.93	3.01	68.92	3.31	69
70	69.96	2.44	69.95	2.75	69.93	3.05	69.92	3.36	70
71	70.96	2.48	70.95	2.79	70.93	3.10	70.92	3.41	71
72	71.96	2.51	71.94	2.83	71.93	3.14	71.92	3.45	72
73	72.96	2.55	72.94	2.87	72.93	3.18	72.92	3.50	73
74	73.95	2.58	73.94	2.91	73.93	3.23	73.91	3.55	74
75	74.95	2.62	74.94	2.94	74.93	3.27	74.91	3.60	75
76	75.95	2.65	75.94	2.98	75.93	3.31	75.91	3.65	76
77	76.95	2.69	76.94	3.02	76.93	3.36	76.91	3.70	77
78	77.95	2.72	77.94	3.06	77.93	3.40	77.91	3.74	78
79	78.95	2.76	78.94	3.10	78.92	3.45	78.91	3.79	79
80	79.95	2.79	79.94	3.14	79.92	3.49	79.91	3.84	80
81	80.95	2.83	80.94	3.18	80.92	3.53	80.91	3.89	81
82	81.95	2.86	81.94	3.22	81.92	3.58	81.91	3.93	82
83	82.95	2.90	82.94	3.26	82.92	3.62	82.90	3.98	83
84	83.95	2.93	83.94	3.30	83.92	3.66	83.90	4.03	84
85	84.95	2.97	84.93	3.34	84.92	3.71	84.90	4.08	85
86	85.95	3.00	85.93	3.38	85.92	3.75	85.90	4.13	86
87	86.95	3.04	86.93	3.42	86.92	3.79	86.90	4.17	87
88	87.95	3.07	87.93	3.45	87.92	3.84	87.90	4.22	88
89	88.95	3.11	88.93	3.49	88.92	3.88	88.90	4.27	89
90	89.95	3.14	89.93	3.53	89.91	3.93	89.90	4.32	90
91	90.95	3.18	90.93	3.57	90.91	3.97	90.90	4.37	91
92	91.94	3.21	91.93	3.61	91.91	4.01	91.89	4.41	92
93	92.94	3.25	92.93	3.65	92.91	4.06	92.89	4.46	93
94	93.94	3.28	93.93	3.69	93.91	4.10	93.89	4.51	94
95	94.94	3.32	94.93	3.73	94.91	4.14	94.89	4.56	95
96	95.94	3.35	95.93	3.77	95.91	4.19	95.89	4.61	96
97	96.94	3.39	96.93	3.81	96.91	4.23	96.89	4.65	97
98	97.94	3.42	97.92	3.85	97.91	4.27	97.89	4.70	98
99	98.94	3.46	98.92	3.89	98.91	4.32	98.89	4.75	99
100	99.94	3.49	99.92	3.93	99.91	4.36	99.88	4.80	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	88 Deg.		87¾ Deg.		87½ Deg.		87¼ Deg.		

Distance.	3 Deg.		3¼ Deg.		3½ Deg.		3¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep	
1	1.00	0.05	1.00	0.06	1.00	0.06	1.00	0.06	1
2	2.00	0.10	2.00	0.11	2.00	0.12	2.00	0.13	2
3	3.00	0.16	3.00	0.17	2.99	0.18	2.99	0.20	3
4	3.99	0.21	3.99	0.23	3.99	0.24	3.99	0.26	4
5	4.99	0.26	4.99	0.28	4.99	0.31	4.99	0.33	5
6	5.99	0.31	5.99	0.34	5.99	0.37	5.99	0.39	6
7	6.99	0.37	6.99	0.40	6.99	0.43	6.99	0.46	7
8	7.99	0.42	7.99	0.45	7.99	0.49	7.98	0.52	8
9	8.99	0.47	8.99	0.51	8.98	0.55	8.98	0.59	9
10	9.99	0.52	9.98	0.57	9.98	0.61	9.98	0.65	10
11	10.98	0.58	10.98	0.62	10.98	0.67	10.98	0.72	11
12	11.98	0.63	11.98	0.68	11.98	0.73	11.97	0.78	12
13	12.98	0.68	12.98	0.73	12.98	0.79	12.97	0.85	13
14	13.98	0.73	13.98	0.79	13.97	0.85	13.97	0.92	14
15	14.98	0.79	14.98	0.85	14.97	0.92	14.97	0.98	15
16	15.98	0.84	15.97	0.91	15.97	0.98	15.97	1.05	16
17	16.98	0.89	16.97	0.96	16.97	1.04	16.96	1.11	17
18	17.98	0.94	17.97	1.02	17.97	1.10	17.96	1.18	18
19	18.98	0.99	18.97	1.08	18.96	1.16	18.96	1.24	19
20	19.97	1.05	19.97	1.13	19.96	1.22	19.96	1.31	20
21	20.97	1.10	20.97	1.19	20.96	1.28	20.96	1.37	21
22	21.97	1.15	21.96	1.25	21.96	1.34	21.95	1.44	22
23	22.97	1.20	22.96	1.30	22.96	1.40	22.95	1.50	23
24	23.97	1.26	23.96	1.36	23.96	1.47	23.95	1.57	24
25	24.97	1.31	24.96	1.42	24.95	1.53	24.95	1.64	25
26	25.96	1.36	25.96	1.47	25.95	1.59	25.94	1.70	26
27	26.96	1.41	26.96	1.53	26.95	1.65	26.94	1.77	27
28	27.96	1.47	27.95	1.59	27.95	1.71	27.94	1.83	28
29	28.96	1.52	28.95	1.64	28.95	1.77	28.94	1.90	29
30	29.96	1.57	29.95	1.70	29.94	1.83	29.94	1.96	30
31	30.96	1.62	30.95	1.76	30.94	1.89	30.93	2.03	31
32	31.96	1.67	31.95	1.81	31.94	1.95	31.93	2.09	32
33	32.95	1.73	32.95	1.87	32.94	2.01	32.93	2.16	33
34	33.95	1.78	33.95	1.93	33.94	2.08	33.93	2.22	34
35	34.95	1.83	34.94	1.98	34.93	2.11	34.92	2.29	35
36	35.95	1.88	35.94	2.04	35.93	2.20	35.92	2.35	36
37	36.95	1.94	36.94	2.10	36.93	2.26	36.92	2.42	37
38	37.95	1.99	37.94	2.15	37.93	2.32	37.92	2.49	38
39	38.95	2.04	38.94	2.21	38.93	2.38	38.92	2.55	39
40	39.95	2.09	39.94	2.27	39.93	2.44	39.91	2.62	40
41	40.94	2.15	40.93	2.32	40.92	2.50	40.91	2.68	41
42	41.94	2.20	41.93	2.38	41.92	2.56	41.91	2.75	42
43	42.94	2.25	42.93	2.44	42.92	2.63	42.91	2.81	43
44	43.94	2.30	43.93	2.49	43.92	2.69	43.91	2.88	44
45	44.94	2.36	44.93	2.55	44.92	2.75	44.90	2.94	45
46	45.94	2.41	45.93	2.61	45.91	2.81	45.90	3.01	46
47	46.94	2.46	46.92	2.66	46.91	2.87	46.90	3.07	47
48	47.93	2.51	47.92	2.72	47.91	2.93	47.90	3.14	48
49	48.93	2.56	48.92	2.78	48.91	2.99	48.90	3.20	49
50	49.93	2.62	49.92	2.83	49.91	3.05	49.89	3.27	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	87 Deg.		86¾ Deg.		86½ Deg.		86¼ Deg.		

Distance.	3 Deg.		3¼ Deg.		3½ Deg.		3¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	50.93	2.67	50.92	2.89	50.90	3.11	50.89	3.34	51
52	51.93	2.72	51.92	2.95	51.90	3.17	51.89	3.40	52
53	52.93	2.77	52.91	3.00	52.90	3.24	52.89	3.47	53
54	53.93	2.83	53.91	3.06	53.90	3.30	53.88	3.53	54
55	54.92	2.88	54.91	3.12	54.90	3.36	54.88	3.60	55
56	55.92	2.93	55.91	3.17	55.90	3.42	55.88	3.66	56
57	56.92	2.98	56.91	3.23	56.89	3.48	56.88	3.73	57
58	57.92	3.04	57.91	3.29	57.89	3.54	57.88	3.79	58
59	58.92	3.09	58.91	3.34	58.89	3.60	58.87	3.86	59
60	59.92	3.14	59.90	3.40	59.89	3.66	59.87	3.92	60
61	60.92	3.19	60.90	3.46	60.89	3.72	60.87	3.99	61
62	61.92	3.24	61.90	3.51	61.88	3.79	61.87	4.05	62
63	62.91	3.30	62.90	3.57	62.88	3.85	62.87	4.12	63
64	63.91	3.35	63.90	3.63	63.88	3.91	63.86	4.19	64
65	64.91	3.40	64.90	3.69	64.88	3.97	64.86	4.25	65
66	65.91	3.45	65.89	3.74	65.88	4.03	65.86	4.32	66
67	66.91	3.51	66.89	3.80	66.88	4.09	66.86	4.38	67
68	67.91	3.56	67.89	3.86	67.87	4.15	67.85	4.45	68
69	68.91	3.61	68.89	3.91	68.87	4.21	68.85	4.51	69
70	69.90	3.66	69.89	3.97	69.87	4.27	69.85	4.58	70
71	70.90	3.72	70.89	4.03	70.87	4.33	70.85	4.64	71
72	71.90	3.77	71.88	4.08	71.87	4.40	71.85	4.71	72
73	72.90	3.82	72.88	4.14	72.86	4.46	72.84	4.77	73
74	73.90	3.87	73.88	4.20	73.86	4.52	73.84	4.84	74
75	74.90	3.93	74.88	4.25	74.86	4.58	74.84	4.91	75
76	75.90	3.98	75.88	4.31	75.86	4.64	75.84	4.97	76
77	76.89	4.03	76.88	4.37	76.86	4.70	76.84	5.04	77
78	77.89	4.08	77.87	4.42	77.85	4.76	77.83	5.10	78
79	78.89	4.13	78.87	4.48	78.85	4.82	78.83	5.17	79
80	79.89	4.19	79.87	4.54	79.85	4.88	79.83	5.23	80
81	80.89	4.24	80.87	4.59	80.85	4.94	80.83	5.30	81
82	81.89	4.29	81.87	4.65	81.85	5.01	81.82	5.36	82
83	82.89	4.34	82.87	4.71	82.85	5.07	82.82	5.43	83
84	83.88	4.40	83.86	4.76	83.84	5.13	83.82	5.49	84
85	84.88	4.45	84.86	4.82	84.84	5.19	84.82	5.56	85
86	85.88	4.50	85.86	4.88	85.84	5.25	85.82	5.62	86
87	86.88	4.55	86.86	4.93	86.84	5.31	86.81	5.69	87
88	87.88	4.61	87.86	4.99	87.84	5.37	87.81	5.76	88
89	88.88	4.66	88.86	5.05	88.83	5.43	88.81	5.82	89
90	89.88	4.71	89.86	5.10	89.83	5.49	89.81	5.89	90
91	90.88	4.76	90.85	5.16	90.83	5.56	90.81	5.95	91
92	91.87	4.81	91.85	5.22	91.83	5.62	91.80	6.02	92
93	92.87	4.87	92.85	5.27	92.83	5.68	92.80	6.08	93
94	93.87	4.92	93.85	5.33	93.82	5.74	93.80	6.15	94
95	94.87	4.97	94.85	5.39	94.82	5.80	94.80	6.21	95
96	95.87	5.02	95.85	5.44	95.82	5.86	95.79	6.28	96
97	96.87	5.08	96.84	5.50	96.82	5.92	96.79	6.34	97
98	97.87	5.13	97.84	5.56	97.82	5.98	97.79	6.41	98
99	98.86	5.18	98.84	5.61	98.82	6.04	98.79	6.47	99
100	99.86	5.23	99.84	5.67	99.81	6.10	99.79	6.54	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	87 Deg.		86¾ Deg.		86½ Deg.		86¼ Deg.		

Distance.	4 Deg.		4¼ Deg.		4½ Deg.		4¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	1.00	0.07	1.00	0.07	1.00	0.08	1.00	0.08	1
2	2.00	0.14	1.99	0.15	1.99	0.16	1.99	0.17	2
3	2.99	0.21	2.99	0.22	2.99	0.24	2.99	0.25	3
4	3.99	0.28	3.99	0.30	3.99	0.31	3.98	0.33	4
5	4.99	0.35	4.99	0.37	4.98	0.39	4.98	0.41	5
6	5.99	0.42	5.98	0.44	5.98	0.47	5.98	0.50	6
7	6.98	0.49	6.98	0.52	6.98	0.55	6.97	0.58	7
8	7.98	0.56	7.98	0.59	7.98	0.63	7.97	0.66	8
9	8.98	0.63	8.98	0.67	8.97	0.71	8.97	0.75	9
10	9.98	0.70	9.97	0.74	9.97	0.78	9.97	0.83	10
11	10.97	0.77	10.97	0.82	10.97	0.86	10.96	0.91	11
12	11.97	0.84	11.97	0.89	11.96	0.94	11.96	0.99	12
13	12.97	0.91	12.96	0.96	12.96	1.02	12.96	1.08	13
14	13.97	0.98	13.96	1.04	13.96	1.10	13.95	1.16	14
15	14.96	1.05	14.96	1.11	14.95	1.18	14.95	1.24	15
16	15.96	1.12	15.96	1.19	15.95	1.26	15.95	1.32	16
17	16.96	1.19	16.95	1.26	16.95	1.33	16.94	1.41	17
18	17.96	1.26	17.95	1.33	17.94	1.41	17.94	1.49	18
19	18.95	1.33	18.95	1.40	18.94	1.49	18.93	1.57	19
20	19.95	1.40	19.95	1.48	19.94	1.57	19.93	1.66	20
21	20.95	1.46	20.94	1.56	20.94	1.65	20.93	1.74	21
22	21.95	1.53	21.94	1.63	21.93	1.73	21.92	1.82	22
23	22.94	1.60	22.94	1.70	22.93	1.80	22.92	1.90	23
24	23.94	1.67	23.93	1.78	23.93	1.88	23.92	1.99	24
25	24.94	1.74	24.93	1.85	24.92	1.96	24.91	2.07	25
26	25.94	1.81	25.93	1.93	25.92	2.04	25.91	2.15	26
27	26.93	1.88	26.93	2.00	26.92	2.12	26.91	2.24	27
28	27.93	1.95	27.92	2.08	27.91	2.20	27.90	2.32	28
29	28.93	2.02	28.92	2.15	28.91	2.28	28.90	2.40	29
30	29.93	2.09	29.92	2.22	29.91	2.35	29.90	2.48	30
31	30.92	2.16	30.91	2.30	30.90	2.43	30.89	2.57	31
32	31.92	2.23	31.91	2.37	31.90	2.51	31.89	2.65	32
33	32.92	2.30	32.91	2.45	32.90	2.59	32.89	2.73	33
34	33.92	2.37	33.91	2.52	33.90	2.67	33.88	2.82	34
35	34.91	2.44	34.90	2.59	34.89	2.75	34.88	2.90	35
36	35.91	2.51	35.90	2.67	35.89	2.82	35.88	2.98	36
37	36.91	2.58	36.90	2.74	36.89	2.90	36.87	3.06	37
38	37.91	2.65	37.90	2.82	37.88	2.98	37.87	3.15	38
39	38.90	2.72	38.89	2.89	38.88	3.06	38.87	3.23	39
40	39.90	2.79	39.89	2.96	39.88	3.14	39.86	3.31	40
41	40.90	2.86	40.89	3.04	40.87	3.22	40.86	3.40	41
42	41.90	2.93	41.88	3.11	41.87	3.30	41.86	3.48	42
43	42.90	3.00	42.88	3.19	42.87	3.37	42.85	3.56	43
44	43.89	3.07	43.88	3.26	43.86	3.45	43.85	3.64	44
45	44.89	3.14	44.88	3.33	44.86	3.53	44.85	3.73	45
46	45.89	3.21	45.87	3.41	45.86	3.61	45.84	3.81	46
47	46.89	3.28	46.87	3.48	46.86	3.69	46.84	3.89	47
48	47.88	3.35	47.87	3.56	47.85	3.77	47.84	3.97	48
49	48.88	3.42	48.87	3.63	48.85	3.84	48.83	4.06	49
50	49.88	3.49	49.86	3.71	49.85	3.92	49.83	4.14	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	86 Deg.		85¾ Deg.		85½ Deg.		85¼ Deg.		

Distance.	4 Deg.		4¼ Deg.		4½ Deg.		4¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	50.88	3.56	50.86	3.78	50.84	4.00	50.82	4.22	51
52	51.87	3.63	51.86	3.85	51.84	4.08	51.82	4.31	52
53	52.87	3.70	52.85	3.93	52.84	4.16	52.82	4.39	53
54	53.87	3.77	53.85	4.00	53.83	4.24	53.81	4.47	54
55	54.87	3.84	54.85	4.08	54.83	4.32	54.81	4.55	55
56	55.86	3.91	55.85	4.15	55.83	4.39	55.81	4.64	56
57	56.86	3.98	56.84	4.22	56.82	4.47	56.80	4.72	57
58	57.86	4.05	57.84	4.30	57.82	4.55	57 80	4.80	58
59	58.86	4.12	58.84	4.37	58.82	4.63	58.80	4.89	59
60	59.85	4.19	59.84	4.45	59.82	4.71	59.79	4.97	60
61	60.85	4.26	60.83	4.52	60.81	4.79	60.79	5.05	61
62	61.85	4.32	61.83	4.59	61.81	4.86	61.79	5.13	62
63	62.85	4.39	62.83	4.67	62.81	4.94	62.78	5.22	63
64	63.84	4.46	63.82	4.74	63.80	5.02	63.78	5.30	64
65	64.84	4.53	64.82	4.82	64.80	5.10	64.78	5.38	65
66	65.84	4.60	65.82	4.89	65.80	5.18	65.77	5.47	66
67	66.84	4.67	66.82	4.97	66.79	5.26	66.77	5.55	67
68	67.83	4.74	67.81	5.04	67.79	5.34	67.77	5.63	68
69	68.83	4.81	68.81	5.11	68.79	5.41	68.76	5.71	69
70	69.83	4.88	69.81	5.19	69.78	5.49	69.76	5.80	70
71	70.83	4.95	70.80	5.26	70.78	5.57	70.76	5.88	71
72	71.82	5.02	71.80	5.34	71.78	5.65	71.75	5.96	72
73	72.82	5.09	72.80	5.41	72.77	5.73	72.75	6.04	73
74	73.82	5.16	73.80	5.48	73.77	5.81	73.75	6.13	74
75	74.82	5.23	74.79	5.56	74.77	5.88	74.74	6.21	75
76	75.81	5.30	75.79	5.63	75.77	5.96	75.74	6.29	76
77	76.81	5.37	76.79	5.71	76.76	6.04	76.74	6.38	77
78	77.81	5.44	77.79	5.78	77.76	6.12	77.73	6.46	78
79	78.81	5.51	78.78	5.85	78.76	6.20	78.73	6.54	79
80	79.81	5.58	79.78	5.93	79.75	6.28	79.73	6.62	80
81	80.80	5.65	80.78	6.00	80.75	6.36	80.72	6.71	81
82	81.80	5.72	81.78	6.08	81.75	6.43	81.72	6.79	82
83	82.80	5.79	82.77	6.15	82.74	6.51	82.71	6.87	83
84	83.80	5.86	83.77	6.23	83.74	6.59	83.71	6.96	84
85	84.79	5.93	84.77	6.30	84.74	6.67	84.71	7.04	85
86	85.79	6.00	85.76	6.37	85.73	6.75	85.70	7.12	86
87	86.79	6.07	86.76	6.45	86.73	6.83	86.70	7.20	87
88	87.79	6.14	87.76	6.52	87.73	6.90	87.70	7.29	88
89	88.78	6.21	88.76	6.60	88.73	6.98	88.70	7.37	89
90	89.78	6.28	89.75	6.67	89.72	7.06	89.69	7.45	90
91	90.78	6.35	90.75	6.74	90.72	7.14	90.69	7.54	91
92	91.78	6.42	91.75	6.82	91.72	7.22	91.68	7.62	92
93	92.77	6.49	92.74	6.89	92.71	7.30	92.68	7.70	93
94	93.77	6.56	93.74	6.97	93.71	7.38	93.68	7.78	94
95	94.77	6.63	94.74	7.04	94.71	7.45	94.67	7.87	95
96	95.77	6.70	95.74	7.11	95.70	7.53	95.67	7.95	96
97	96.76	6.77	96.73	7.19	96.70	7.61	96.67	8.03	97
98	97.76	6.84	97.73	7.26	97.70	7.69	97.66	8.12	98
99	98.76	6.91	98.73	7.34	98.69	7.77	98.66	8.20	99
100	99.76	6.98	99.73	7.41	99.69	7.85	99.66	8.28	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	86 Deg.		85¾ Deg.		85½ Deg.		85¼ Deg.		

Distance.	5 Deg.		5¼ Deg.		5½ Deg.		5¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	1.00	0.09	1.00	0.09	1.00	0.10	0.99	0.10	1
2	1.99	0.17	1.99	0.18	1.99	0.19	1.99	0.20	2
3	2.99	0.26	2.99	0.27	2.99	0.29	2.98	0.30	3
4	3.98	0.35	3.98	0.37	3.98	0.38	3.98	0.40	4
5	4.98	0.44	4.98	0.46	4.98	0.48	4.97	0.50	5
6	5.98	0.52	5.97	0.55	5.97	0.58	5.97	0.60	6
7	6.97	0.61	6.97	0.64	6.97	0.67	6.96	0.70	7
8	7.97	0.70	7.97	0.73	7.96	0.76	7.96	0.80	8
9	8.97	0.78	8.96	0.82	8.96	0.86	8.95	0.90	9
10	9.96	0.87	9.96	0.92	9.95	0.96	9.95	1.00	10
11	10.96	0.96	10.95	1.01	10.95	1.05	10.94	1.10	11
12	11.95	1.05	11.95	1.10	11.94	1.15	11.94	1.20	12
13	12.95	1.13	12.95	1.19	12.94	1.25	12.93	1.30	13
14	13.95	1.22	13.94	1.28	13.94	1.34	13.93	1.40	14
15	14.94	1.31	14.94	1.37	14.93	1.44	14.92	1.50	15
16	15.94	1.39	15.93	1.46	15.93	1.53	15.92	1.60	16
17	16.94	1.48	16.93	1.56	16.92	1.63	16.91	1.70	17
18	17.93	1.57	17.92	1.65	17.92	1.73	17.91	1.80	18
19	18.93	1.66	18.92	1.74	18.91	1.82	18.90	1.90	19
20	19.92	1.74	19.92	1.83	19.91	1.92	19.90	2.00	20
21	20.92	1.83	20.91	1.92	20.90	2.01	20.89	2.10	21
22	21.92	1.92	21.91	2.01	21.90	2.11	21.89	2.20	22
23	22.91	2.00	22.90	2.10	22.89	2.20	22.88	2.30	23
24	23.91	2.09	23.90	2.20	23.89	2.30	23.88	2.40	24
25	24.90	2.18	24.90	2.29	24.88	2.40	24.87	2.50	25
26	25.90	2.27	25.89	2.38	25.88	2.49	25.87	2.60	26
27	26.90	2.35	26.89	2.47	26.88	2.59	26.86	2.71	27
28	27.89	2.44	27.88	2.56	27.87	2.68	27.86	2.81	28
29	28.89	2.53	28.88	2.65	28.87	2.78	28.85	2.91	29
30	29.89	2.61	29.87	2.75	29.86	2.88	29.85	3.01	30
31	30.88	2.70	30.87	2.84	30.86	2.97	30.84	3.11	31
32	31.88	2.79	31.87	2.93	31.85	3.07	31.84	3.21	32
33	32.87	2.88	32.86	3.02	32.85	3.16	32.83	3.31	33
34	33.87	2.96	33.86	3.11	33.84	3.26	33.83	3.41	34
35	34.87	3.05	34.85	3.20	34.84	3.35	34.82	3.51	35
36	35.86	3.14	35.85	3.29	35.83	3.45	35.82	3.61	36
37	36.86	3.22	36.84	3.39	36.83	3.55	36.81	3.71	37
38	37.86	3.31	37.84	3.48	37.83	3.64	37.81	3.81	38
39	38.85	3.40	38.84	3.57	38.82	3.74	38.80	3.91	39
40	39.85	3.49	39.83	3.66	39.82	3.83	39.80	4.01	40
41	40.84	3.57	40.83	3.75	40.81	3.93	40.79	4.11	41
42	41.84	3.66	41.82	3.84	41.81	4.03	41.79	4.21	42
43	42.84	3.75	42.82	3.93	42.80	4.12	42.78	4.31	43
44	43.83	3.83	43.82	4.03	43.80	4.22	43.78	4.41	44
45	44.83	3.92	44.81	4.12	44.79	4.31	44.77	4.51	45
46	45.82	4.01	45.81	4.21	45.79	4.41	45.77	4.61	46
47	46.82	4.10	46.80	4.30	46.78	4.50	46.76	4.71	47
48	47.82	4.18	47.80	4.39	47.78	4.60	47.76	4.81	48
49	48.81	4.27	48.79	4.48	48.77	4.70	48.75	4.91	49
50	49.81	4.36	49.79	4.58	49.77	4.79	49.75	5.01	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	85 Deg.		84¾ Deg.		84½ Deg.		84¼ Deg.		

Distance.	5 Deg.		5¼ Deg.		5½ Deg.		5¾ Deg		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	50.81	4.44	50.79	4.67	50.77	4.89	50.74	5.11	51
52	51.80	4.53	51.78	4.76	51.76	4.98	51.74	5.21	52
53	52.80	4.62	52.78	4.85	52.76	5.08	52.73	5.31	53
54	53.79	4.71	53.77	4.94	53.75	5.18	53.73	5.41	54
55	54.79	4.79	54.77	5.03	54.75	5.27	54.72	5.51	55
56	55.79	4.88	55.77	5.12	55.74	5.37	55.72	5.61	56
57	56.78	4.97	56.76	5.22	56.74	5.46	56.71	5.71	57
58	57.78	5.06	57.76	5.31	57.73	5.56	57.71	5.81	58
59	58.78	5.14	58.75	5.40	58.73	5.65	58.70	5.91	59
60	59.77	5.23	59.75	5.49	59.72	5.75	59.70	6.01	60
61	60.77	5.32	60.74	5.58	60.72	5.85	60.69	6.11	61
62	61.76	5.40	61.74	5.67	61.71	5.94	61.69	6.21	62
63	62.76	5.49	62.74	5.76	62.71	6.04	62.68	6.31	63
64	63.76	5.58	63.73	5.86	63.71	6.13	63.68	6.41	64
65	64.75	5.67	64.73	5.95	64.70	6.23	64.67	6.51	65
66	65.75	5.75	65.72	6.04	65.70	6.33	65.67	6.61	66
67	66.75	5.84	66.72	6.13	66.69	6.42	66.66	6.71	67
68	67.74	5.93	67.71	6.22	67.69	6.52	67.66	6.81	68
69	68.74	6.01	68.71	6.31	68.68	6.61	68.65	6.91	69
70	69.73	6.10	69.71	6.41	69.68	6.71	69.65	7.01	70
71	70.73	6.19	70.70	6.50	70.67	6.81	70.64	7.11	71
72	71.73	6.28	71.70	6.59	71.67	6.90	71.64	7.21	72
73	72.72	6.36	72.69	6.68	72.66	7.00	72.63	7.31	73
74	73.72	6.45	73.69	6.77	73.66	7.09	73.63	7.41	74
75	74.71	6.54	74.69	6.86	74.65	7.19	74.62	7.51	75
76	75.71	6.62	75.68	6.95	75.65	7.28	75.62	7.61	76
77	76.71	6.71	76.68	7.05	76.65	7.38	76.61	7.71	77
78	77.70	6.80	77.67	7.14	77.64	7.48	77.61	7.81	78
79	78.70	6.89	78.67	7.23	78.64	7.57	78.60	7.91	79
80	79.70	6.97	79.66	7.32	79.65	7.67	79.60	8.02	80
81	80.69	7.06	80.66	7.41	80.63	7.76	80.59	8.12	81
82	81.69	7.15	81.66	7.50	81.62	7.86	81.59	8.22	82
83	82.68	7.23	82.65	7.59	82.62	7.96	82.58	8.32	83
84	83.68	7.32	83.65	7.69	83.61	8.05	83.58	8.42	84
85	84.68	7.41	84.64	7.78	84.61	8.15	84.57	8.52	85
86	85.67	7.50	85.64	7.87	85.60	8.24	85.57	8.62	86
87	86.67	7.58	86.64	7.96	86.60	8.34	86.56	8.72	87
88	87.67	7.67	87.63	8.05	87.59	8.43	87.56	8.82	88
89	88.66	7.76	88.63	8.14	88.59	8.53	88.55	8.92	89
90	89.66	7.84	89.62	8.24	89.59	8.63	89.55	9.02	90
91	90.65	7.93	90.62	8.33	90.58	8.72	90.54	9.12	91
92	91.65	8.02	91.61	8.42	91.58	8.82	91.54	9.22	92
93	92.65	8.11	92.61	8.51	92.57	8.91	92.53	9.32	93
94	93.64	8.19	93.61	8.60	93.57	9.01	93.53	9.42	94
95	94.64	8.28	94.60	8.69	94.56	9.11	94.52	9.52	95
96	95.63	8.37	95.60	8.78	95.56	9.20	95.52	9.62	96
97	96.63	8.45	96.59	8.88	96.55	9.30	96.51	9.72	97
98	97.63	8.54	97.59	8.97	97.55	9.39	97.51	9.82	98
99	98.62	8.63	98.59	9.06	98.54	9.49	98.50	9.92	99
100	99.62	8.72	99.58	9.15	99.54	9.58	99.50	10.02	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat	Distance.
	85 Deg.		84¾ Deg.		84½ Deg.		84¼ Deg		

Distance.	6 Deg.		6¼ Deg.		6½ Deg.		6¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.99	0.10	0.99	0.11	0.99	0.11	0.99	0.12	1
2	1.99	0.21	1.99	0.22	1.99	0.23	1.99	0.24	2
3	2.98	0.31	2.98	0.33	2.98	0.34	2.98	0.35	3
4	3.98	0.41	3.98	0.44	3.97	0.45	3.97	0.47	4
5	4.97	0.52	4.97	0.54	4.97	0.57	4.97	0.59	5
6	5.97	0.63	5.96	0.65	5.96	0.68	5.96	0.71	6
7	6.96	0.73	6.96	0.76	6.96	0.79	6.95	0.82	7
8	7.96	0.84	7.95	0.87	7.95	0.91	7.94	0.94	8
9	8.95	0.94	8.95	0.98	8.94	1.02	8.94	1.06	9
10	9.95	1.05	9.94	1.09	9.94	1.13	9.93	1.18	10
11	10.94	1.15	10.93	1.20	10.93	1.25	10.92	1.29	11
12	11.93	1.25	11.93	1.31	11.92	1.36	11.92	1.41	12
13	12.93	1.36	12.92	1.42	12.92	1.47	12.91	1.53	13
14	13.92	1.46	13.92	1.52	13.91	1.59	13.90	1.65	14
15	14.92	1.57	14.91	1.63	14.90	1.70	14.90	1.76	15
16	15.91	1.67	15.90	1.74	15.90	1.81	15.89	1.88	16
17	16.91	1.78	16.90	1.85	16.89	1.92	16.88	2.00	17
18	17.90	1.88	17.89	1.96	17.88	2.04	17.88	2.12	18
19	18.90	1.99	18.89	2.07	18.88	2.15	18.87	2.23	19
20	19.89	2.09	19.88	2.18	19.87	2.26	19.86	2.35	20
21	20.88	2.20	20.88	2.29	20.87	2.38	20.85	2.47	21
22	21.88	2.30	21.87	2.40	21.86	2.49	21.85	2.59	22
23	22.87	2.40	22.86	2.50	22.85	2.60	22.84	2.70	23
24	23.87	2.51	23.86	2.61	23.85	2.72	23.83	2.82	24
25	24.86	2.61	24.85	2.72	24.84	2.83	24.83	2.94	25
26	25.86	2.72	25.85	2.83	25.83	2.94	25.82	3.06	26
27	26.85	2.82	26.84	2.94	26.83	3.06	26.81	3.17	27
28	27.85	2.93	27.83	3.05	27.82	3.17	27.81	3.29	28
29	28.84	3.03	28.83	3.16	28.81	3.28	28.80	3.41	29
30	29.84	3.14	29.82	3.27	29.81	3.40	29.79	3.53	30
31	30.83	3.24	30.82	3.37	30.80	3.51	30.79	3.64	31
32	31.82	3.34	31.81	3.48	31.79	3.62	31.78	3.76	32
33	32.82	3.45	32.80	3.59	32.79	3.74	32.77	3.88	33
34	33.81	3.55	33.80	3.70	33.78	3.85	33.76	4.00	34
35	34.81	3.66	34.79	3.81	34.78	3.96	34.76	4.11	35
36	35.80	3.76	35.79	3.92	35.77	4.08	35.75	4.23	36
37	36.80	3.87	36.78	4.03	36.76	4.19	36.75	4.35	37
38	37.79	3.97	37.77	4.14	37.76	4.30	37.74	4.47	38
39	38.79	4.08	38.77	4.25	38.75	4.41	38.73	4.58	39
40	39.78	4.18	39.76	4.35	39.74	4.53	39.72	4.70	40
41	40.78	4.29	40.76	4.46	40.74	4.64	40.72	4.82	41
42	41.77	4.39	41.75	4.57	41.73	4.76	41.71	4.94	42
43	42.76	4.49	42.74	4.68	42.72	4.87	42.70	5.05	43
44	43.76	4.60	43.74	4.79	43.72	4.98	43.70	5.17	44
45	44.75	4.70	44.73	4.90	44.71	5.09	44.69	5.29	45
46	45.75	4.81	45.73	5.01	45.70	5.21	45.68	5.41	46
47	46.74	4.91	46.72	5.12	46.70	5.32	46.67	5.52	47
48	47.74	5.02	47.71	5.23	47.69	5.43	47.67	5.64	48
49	48.73	5.12	48.71	5.34	48.69	5.55	48.66	5.76	49
50	49.73	5.23	49.70	5.44	49.68	5.66	49.65	5.88	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	84 Deg.		83¾ Deg.		83½ Deg.		83¼ Deg.		

Distance.	6 Deg.		6¼ Deg.		6½ Deg		6¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat	Dep.	Lat.	Dep.	
51	50.72	5.33	50.70	5.55	50.67	5.77	50.65	5.99	51
52	51.72	5.44	51.69	5.66	51.67	5.89	51.64	6.11	52
53	52.71	5.54	52.68	5.77	52.66	6.00	52.63	6.23	53
54	53.70	5.64	53.68	5.88	53.65	6.11	53.63	6.35	54
55	54.70	5.75	54.67	5.99	54.65	6.23	54.62	6.16	55
56	55.69	5.85	55.67	6.10	55.64	6.34	55.61	6.58	56
57	56.69	5.96	56.66	6.21	56.63	6.45	56.60	6.70	57
58	57.68	6.06	57.66	6.31	57.63	6.57	57.60	6.82	58
59	58.68	6.17	58.65	6.42	58.62	6.68	58.59	6.93	59
60	59.67	6.27	59.64	6.53	59.61	6.79	59.58	7.05	60
61	60.67	6.38	60.64	6.64	60.61	6.91	60.58	7.17	61
62	61.66	6.48	61.63	6.75	61.60	7.02	61.57	7.29	62
63	62.65	6.59	62.63	6.86	62.60	7.13	62.56	7.40	63
64	63.65	6.69	63.62	6.97	63.59	7.25	63.56	7.52	64
65	64.64	6.79	64.61	7.08	64.58	7.36	64.55	7.64	65
66	65.64	6.90	65.61	7.19	65.58	7.47	65.54	7.76	66
67	66.63	7.00	66.60	7.29	66.57	7.58	66.54	7.88	67
68	67.63	7.11	67.60	7.40	67.56	7.70	67.53	7.99	68
69	68.62	7.21	68.59	7.51	68.56	7.81	68.52	8.11	69
70	69.62	7.32	69.58	7.62	69.55	7.92	69.51	8.23	70
71	70.61	7.42	70.58	7.73	70.54	8.04	70.51	8.35	71
72	71.61	7.53	71.57	7.84	71.54	8.15	71.50	8.46	72
73	72.60	7.63	72.57	7.95	72.53	8.26	72.49	8.58	73
74	73.59	7.74	73.56	8.06	73.52	8.38	73.49	8.70	74
75	74.59	7.84	74.55	8.17	74.52	8.49	74.48	8.82	75
76	75.58	7.94	75.55	8.27	75.51	8.60	75.47	8.93	76
77	76.58	8.05	76.54	8.38	76.51	8.72	76.47	9.05	77
78	77.57	8.15	77.54	8.49	77.50	8.83	77.46	9.17	78
79	78.57	8.26	78.53	8.60	78.49	8.94	78.45	9.29	79
80	79.56	8.36	79.53	8.71	79.49	9.06	79.45	9.40	80
81	80.56	8.47	80.52	8.82	80.48	9.17	80.44	9.52	81
82	81.55	8.57	81.51	8.93	81.47	9.28	81.43	9.64	82
83	82.55	8.68	82.51	9.04	82.47	9.40	82.42	9.76	83
84	83.54	8.78	83.50	9.14	83.46	9.51	83.42	9.87	84
85	84.53	8.88	84.50	9.25	84.45	9.62	84.41	9.99	85
86	85.53	8.99	85.49	9.36	85.45	9.74	85.40	10.11	86
87	86.52	9.09	86.48	9.47	86.44	9.85	86.40	10.23	87
88	87.52	9.20	87.48	9.58	87.43	9.96	87.39	10.34	88
89	88.51	9.30	88.47	9.69	88.43	10.08	88.38	10.46	89
90	89.51	9.41	89.47	9.80	89.42	10.19	89.38	10.58	90
91	90.50	9.51	90.46	9.91	90.42	10.30	90.37	10.70	91
92	91.50	9.62	91.45	10.02	91.41	10.41	91.36	10.81	92
93	92.49	9.72	92.45	10.12	92.40	10.53	92.36	10.93	93
94	93.49	9.83	93.44	10.23	93.40	10.64	93.35	11.05	94
95	94.48	9.93	94.44	10.34	94.39	10.75	94.34	11.17	95
96	95.47	10.03	95.43	10.45	95.38	10.87	95.33	11.28	96
97	96.47	10.14	96.42	10.56	96.38	10.98	96.33	11.40	97
98	97.46	10.24	97.42	10.67	97.37	11.09	97.32	11.52	98
99	98.46	10.35	98.41	10.78	98.36	11.21	98.31	11.64	99
100	99.45	10.45	99.41	10.89	99.36	11.32	99.31	11.75	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	84 Deg.		83¾ Deg.		83½ Deg.		83¼ Deg.		

Distance.	Deg.		7¼ Deg.		7½ Deg		7¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.99	0.12	0.99	0.13	0.99	0.13	0.99	0.13	1
2	1.99	0.24	1.98	0.25	1.98	0.26	1.98	0.27	2
3	2.98	0.37	2.98	0.38	2.97	0.39	2.97	0.40	3
4	3.97	0.49	3.97	0.50	3.97	0.52	3.96	0.54	4
5	4.96	0.61	4.96	0.63	4.96	0.65	4.95	0.67	5
6	5.96	0.73	5.95	0.76	5.95	0.78	5.95	0.81	6
7	6.95	0.85	6.94	0.88	6.94	0.91	6.94	0.94	7
8	7.94	0.97	7.94	1.01	7.93	1.04	7.93	1.08	8
9	8.93	1.10	8.93	1.14	8.92	1.17	8.92	1.21	9
10	9.93	1.22	9.92	1.26	9.91	1.31	9.91	1.35	10
11	10.92	1.34	10.91	1.39	10.91	1.44	10.90	1.48	11
12	11.91	1.46	11.90	1.51	11.90	1.57	11.89	1.62	12
13	12.90	1.58	12.90	1.64	12.89	1.70	12.88	1.75	13
14	13.90	1.71	13.89	1.77	13.88	1.83	13.87	1.89	14
15	14.89	1.83	14.88	1.89	14.87	1.96	14.86	2.02	15
16	15.88	1.95	15.87	2.02	15.86	2.09	15.85	2.16	16
17	16.87	2.07	16.86	2.15	16.85	2.22	16.84	2.29	17
18	17.87	2.19	17.86	2.27	17.85	2.25	17.84	2.43	18
19	18.86	2.32	18.85	2.40	18.84	2.48	18.83	2.56	19
20	19.85	2.44	19.84	2.52	19.83	2.61	19.82	2.70	20
21	20.84	2.56	20.83	2.65	20.82	2.74	20.81	2.83	21
22	21.84	2.68	21.82	2.78	21.81	2.87	21.80	2.97	22
23	22.83	2.80	22.82	2.90	22.80	3.00	22.79	3.10	23
24	23.82	2.92	23.81	3.03	23.79	3.13	23.78	3.24	24
25	24.81	3.05	24.80	3.15	24.79	3.26	24.77	3.37	25
26	25.81	3.17	25.79	3.28	25.78	3.39	25.76	3.51	26
27	26.80	3.29	26.78	3.41	26.77	3.52	26.75	3.64	27
28	27.79	3.41	27.78	3.53	27.76	3.65	27.74	3.78	28
29	28.78	3.53	28.77	3.66	28.75	3.79	28.74	3.91	29
30	29.78	3.66	29.76	3.79	29.74	3.92	29.73	4.05	30
31	30.77	3.78	30.75	3.91	30.73	4.05	30.72	4.18	31
32	31.76	3.90	31.74	4.04	31.73	4.18	31.71	4.32	32
33	32.75	4.02	32.74	4.16	32.72	4.31	32.70	4.45	33
34	33.75	4.14	33.73	4.29	33.71	4.44	33.69	4.58	34
35	34.74	4.27	34.72	4.42	34.70	4.57	34.68	4.72	35
36	35.73	4.39	35.71	4.54	35.69	4.70	35.67	4.85	36
37	36.72	4.51	36.70	4.67	36.68	4.83	36.66	4.99	37
38	37.72	4.63	37.70	4.80	37.67	4.96	37.65	5.12	38
39	38.71	4.75	38.69	4.92	38.67	5.09	38.64	5.26	39
40	39.70	4.87	39.68	5.05	39.66	5.22	39.63	5.39	40
41	40.70	5.00	40.67	5.17	40.65	5.35	40.63	5.53	41
42	41.69	5.12	41.66	5.30	41.64	5.48	41.62	5.66	42
43	42.68	5.24	42.66	5.43	42.63	5.61	42.61	5.80	43
44	43.67	5.36	43.65	5.55	43.62	5.74	43.60	5.93	44
45	44.67	5.48	44.64	5.68	44.62	5.87	44.59	6.07	45
46	45.66	5.61	45.63	5.81	45.61	6.00	45.58	6.20	46
47	46.65	5.73	46.62	5.93	46.60	6.13	46.57	6.34	47
48	47.64	5.85	47.62	6.06	47.59	6.27	47.56	6.47	48
49	48.63	5.97	48.61	6.18	48.58	6.40	48.55	6.61	49
50	49.63	6.09	49.60	6.31	49.57	6.53	49.54	6.74	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	83 Deg.		82¾ Deg.		82½ Deg.		82¼ Deg.		

Distance.	7 Deg.		7¼ Deg.		7½ Deg.		7¾ Dep.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	50.62	6.22	50.59	6.44	50.56	6.66	50.53	6.88	51
52	51.61	6.34	51.58	6.56	51.56	6.79	51.53	7 01	52
53	52.60	6.46	52.58	6.69	52.55	6.92	52.52	7.15	53
54	53.60	6.58	53.57	6.81	53.54	7.05	53.51	7.28	54
55	54.59	6 70	54.56	6.94	54.53	7 18	54.50	7.42	55
56	55.58	6.82	55.55	7.07	55.52	7 31	55.49	7.55	56
57	56.58	6.95	56.54	7.19	56.51	7 44	56.48	7.69	57
58	57.57	7.07	57.54	7.32	57.50	7.57	57.47	7.82	58
59	58.56	7.19	58.53	7.45	58.50	7.70	58.46	7.96	59
60	59.55	7.31	59.52	7.57	59.49	7.83	59.45	8.09	60
61	60.55	7 43	60.51	7.70	60.48	7.96	60.44	8.23	61
62	61.54	7.56	61.50	7.82	61.47	8.09	61.43	8.36	62
63	62.53	7.68	62.50	7.95	62.46	8.22	62.42	8.50	63
64	63.52	7.80	63.49	8.08	63.45	8.35	63.42	8.63	64
65	64.52	7.92	64.48	8.20	64.44	8.48	64.41	8.77	65
66	65.51	8.04	65.47	8.33	65.44	8.61	65.40	8.90	66
67	66 50	8.17	66.46	8.46	66.43	8.75	66.39	9.04	67
68	67.49	8.29	67.46	8.58	67.42	8.88	67.38	9.17	68
69	68.49	8.41	68.45	8.71	68.41	9.01	68.37	9.30	69
70	69.48	8.53	69.44	8.83	69.40	9.14	69.36	9.44	70
71	70.47	8.65	70.43	8.96	70.39	9.27	70.35	9.57	71
72	71.46	8.77	71.42	9.09	71.38	9.40	71.34	9.71	72
73	72.46	8.90	72.42	9.21	72.38	9.53	72.33	9.84	73
74	73.45	9.82	73.41	9.34	73.37	9.66	73.32	9.98	74
75	74.44	9.14	74.40	9.46	74.36	9.79	74.31	10.11	75
76	75.43	9.26	75.39	9.59	75.35	9.92	75.31	10.25	76
77	76.43	9.38	76.38	9.72	76.34	10.05	76.30	10.38	77
78	77.42	9.51	77.38	9.84	77.33	10.18	77.29	10.52	78
79	78.41	9.63	78.37	9.97	78.32	10.31	78.28	10.65	79
80	79.40	9.75	79.36	10.10	79.32	10.44	79.27	10.79	80
81	80.40	9.87	80.35	10.22	80.31	10.57	80.26	10.92	81
82	81.39	9.99	81.34	10.35	81.30	10.70	81.25	11.06	82
83	82.38	10.12	82.34	10.47	82.29	10.83	82.24	11.19	83
84	83.37	10.24	83.33	10.60	83.28	10.96	83.23	11.33	84
85	84.37	10.36	84.32	10.73	84.27	11.09	84.22	11.46	85
86	85.36	10.48	85.31	10.85	85.26	11.23	85.21	11.60	86
87	86.35	10.60	86.30	10.98	86.26	11.36	86.21	11.73	87
88	87.34	10.72	87.30	11.11	87.25	11.49	87.20	11.87	88
89	88.34	10.85	88.29	11.23	88.24	11.62	88.19	12.00	89
90	89.33	10 97	89.28	11.36	89.23	11.75	89.18	12.14	90
91	90.32	11.09	90.27	11.48	90.22	11.88	90.17	12.27	91
92	91.31	11.21	91.26	11.61	91.21	12.01	91.16	12.41	92
93	92.31	11.33	92.26	11.74	92.20	12.14	92.15	12.54	93
94	93.30	11.46	93.25	11.86	93.20	12.27	93.14	12.68	94
95	94.29	11.58	94.24	11.99	94.19	12.40	94.13	12.81	95
96	95.28	11.70	95.23	12.12	95.18	12.53	95.12	12.95	96
97	96.28	11.82	96.22	12.24	96.17	12.66	96.11	13.08	97
98	97.27	11.94	97.22	12.37	97.16	12.79	97.10	13.22	98
99	98.26	12.07	98.21	12.49	98.15	12.92	98.10	13.35	99
100	99.25	12.19	99.20	12.62	99.14	13.05	99.09	13.49	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	83 Deg.		82¾ Deg.		82½ Deg.		82¼ Deg.		

Distance.	8 Deg.		8¼ Deg.		8½ Deg.		8¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.99	0.14	0.99	0.14	0.99	0.15	0.99	0.15	1
2	1.98	0.28	1.98	0.29	1.98	0.30	1.98	0.30	2
3	2.97	0.42	2.97	0.43	2.97	0.44	2.97	0.46	3
4	3.96	0.56	3.96	0.57	3.96	0.59	3.95	0.61	4
5	4.95	0.70	4.95	0.72	4.95	0.74	4.94	0.76	5
6	5.94	0.84	5.94	0.86	5.93	0.89	5.93	0.91	6
7	6.93	0.97	6.93	1.00	6.92	1.03	6.92	1.06	7
8	7.92	1.11	7.92	1.15	7.91	1.18	7.91	1.22	8
9	8.91	1.25	8.91	1.29	8.90	1.33	8.90	1.37	9
10	9.90	1.39	9.90	1.43	9.89	1.48	9.88	1.52	10
11	10.89	1.53	10.89	1.58	10.88	1.63	10.87	1.67	11
12	11.88	1.67	11.88	1.72	11.87	1.77	11.86	1.83	12
13	12.87	1.81	12.87	1.87	12.86	1.92	12.85	1.98	13
14	13.86	1.95	13.86	2.01	13.85	2.07	13.84	2.13	14
15	14.85	2.09	14.85	2.15	14.84	2.22	14.83	2.28	15
16	15.84	2.23	15.84	2.30	15.82	2.36	15.81	2.43	16
17	16.83	2.37	16.83	2.44	16.81	2.51	16.80	2.59	17
18	17.82	2.51	17.81	2.58	17.80	2.66	17.79	2.74	18
19	18.82	2.64	18.80	2.73	18.79	2.81	18.78	2.89	19
20	19.81	2.78	19.79	2.87	19.78	2.96	19.77	3.04	20
21	20.80	2.92	20.78	3.01	20.77	3.10	20.76	3.19	21
22	21.79	3.06	21.77	3.16	21.76	3.25	21.74	3.35	22
23	22.78	3.20	22.76	3.30	22.75	3.40	22.73	3.50	23
24	23.77	3.34	23.75	3.44	23.74	3.55	23.72	3.65	24
25	24.76	3.48	24.74	3.59	24.73	3.70	24.71	3.80	25
26	25.75	3.62	25.73	3.73	25.71	3.84	25.70	3.96	26
27	26.74	3.76	26.72	3.87	26.70	3.99	26.69	4.11	27
28	27.73	3.90	27.71	4.02	27.69	4.14	27.67	4.26	28
29	28.72	4.04	28.70	4.16	28.68	4.29	28.66	4.41	29
30	29.71	4.18	29.69	4.30	29.67	4.43	29.65	4.56	30
31	30.70	4.31	30.68	4.45	30.66	4.58	30.64	4.72	31
32	31.69	4.45	31.67	4.59	31.65	4.73	31.63	4.87	32
33	32.68	4.59	32.66	4.74	32.64	4.88	32.62	5.02	33
34	33.67	4.73	33.65	4.88	33.63	5.03	33.60	5.17	34
35	34.66	4.87	34.64	5.02	34.62	5.17	34.59	5.32	35
36	35.65	5.01	35.63	5.17	35.60	5.32	35.58	5.48	36
37	36.64	5.15	36.62	5.31	36.59	5.47	36.57	5.63	37
38	37.63	5.29	37.61	5.45	37.58	5.62	37.56	5.78	38
39	38.62	5.43	38.60	5.60	38.57	5.76	38.55	5.92	39
40	39.61	5.57	39.59	5.74	39.56	5.91	39.53	6.08	40
41	40.60	5.71	40.58	5.88	40.55	6.06	40.52	6.24	41
42	41.59	5.85	41.57	6.03	41.54	6.21	41.51	6.39	42
43	42.58	5.98	42.56	6.17	42.53	6.36	42.50	6.54	43
44	43.57	6.12	43.54	6.31	43.52	6.50	43.49	6.69	44
45	44.56	6.26	44.53	6.46	44.51	6.65	44.48	6.85	45
46	45.55	6.40	45.52	6.60	45.49	6.80	45.46	7.00	46
47	46.54	6.54	46.5	6.74	46.48	6.95	46.45	7.15	47
48	47.53	6.68	47.50	6.89	47.47	7.09	47.44	7.30	48
49	48.52	6.82	48.49	7.03	48.46	7.24	48.43	7.45	49
50	49.51	6.96	49.48	7.17	49.45	7.39	49.42	7.61	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	82 Deg.		81¾ Deg.		81½ Deg.		81¼ Deg.		

Distance.	8 Deg.		8¼ Deg.		8½ Deg.		8¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	50.50	7.10	50.47	7.32	50.44	7.54	50.41	7.76	51
52	51.49	7.24	51.46	7.46	51.43	7.69	51.39	7.91	52
53	52.48	7.38	52.45	7.61	52.42	7.83	52.38	8.06	53
54	53.47	7.52	53.44	7.75	53.41	7.98	53.37	8.21	54
55	54.46	7.65	54.43	7.89	54.40	8.13	54.36	8.37	55
56	55.46	7.79	55.42	8.04	55.38	8.28	55.35	8.52	56
57	56.45	7.93	56.41	8.18	56.37	8.43	56.34	8.67	57
58	57.44	8.07	57.40	8.32	57.36	8.57	57.32	8.82	58
59	58.43	8.21	58.39	8.47	58.35	8.72	58.31	8.98	59
60	59.42	8.35	59.38	8.61	59.34	8.87	59.30	9.13	60
61	60.41	8.49	60.37	8.75	60.33	9.02	60.29	9.28	61
62	61.40	8.63	61.36	8.90	61.32	9.16	61.28	9.43	62
63	62.39	8.77	62.35	9.04	62.31	9.31	62.27	9.58	63
64	63.38	8.91	63.34	9.18	63.30	9.46	63.26	9.74	64
65	64.37	9.05	64.33	9.33	64.29	9.61	64.24	9.89	65
66	65.36	9.19	65.32	9.47	65.28	9.76	65.23	10.04	66
67	66.35	9.32	66.31	9.61	66.26	9.90	66.22	10.19	67
68	67.34	9.46	67.30	9.76	67.25	10.05	67.21	10.34	68
69	68.33	9.60	68.29	9.90	68.24	10.20	68.20	10.50	69
70	69.32	9.74	69.28	10.04	69.23	10.35	69.19	10.65	70
71	70.31	9.88	70.27	10.19	70.22	10.49	70.17	10.80	71
72	71.30	10.02	71.25	10.33	71.21	10.64	71.16	10.95	72
73	72.29	10.16	72.24	10.47	72.20	10.79	72.15	11.10	73
74	73.28	10.30	73.23	10.62	73.19	10.94	73.14	11.26	74
75	74.27	10.44	74.22	10.76	74.18	11.09	74.13	11.41	75
76	75.26	10.58	75.21	10.91	75.17	11.23	75.12	11.56	76
77	76.25	10.72	76.20	11.05	76.15	11.38	76.10	11.71	77
78	77.24	10.86	77.19	11.19	77.14	11.53	77.09	11.87	78
79	78.23	10.99	78.18	11.34	78.13	11.68	78.08	12.02	79
80	79.22	11.13	79.17	11.48	79.12	11.82	79.07	12.17	80
81	80.21	11.27	80.16	11.62	80.11	11.97	80.06	12.32	81
82	81.20	11.41	81.15	11.77	81.10	12.12	81.05	12.47	82
83	82.19	11.55	82.14	11.91	82.09	12.27	82.03	12.63	83
84	83.18	11.69	83.13	12.05	83.08	12.42	83.02	12.78	84
85	84.17	11.83	84.12	12.20	84.07	12.56	84.01	12.93	85
86	85.16	11.97	85.11	12.34	85.06	12.71	85.00	13.08	86
87	86.15	12.11	86.10	12.48	86.04	12.86	85.99	13.23	87
88	87.14	12.25	87.09	12.63	87.03	13.01	86.98	13.39	88
89	88.13	12.39	88.08	12.77	88.02	13.16	87.96	13.54	89
90	89.12	12.53	89.07	12.91	89.01	13.30	88.95	13.69	90
91	90.11	12.66	90.06	13.06	90.00	13.45	89.94	13.84	91
92	91.10	12.80	91.05	13.20	90.99	13.60	90.93	14.00	92
93	92.09	12.94	92.04	13.34	91.98	13.75	91.92	14.15	93
94	93.09	13.08	93.03	13.49	92.97	13.89	92.91	14.30	94
95	94.08	13.22	94.02	13.63	93.96	14.04	93.89	14.45	95
96	95.07	13.36	95.01	13.78	94.95	14.19	94.88	14.60	96
97	96.06	13.50	96.00	13.92	95.93	14.34	95.87	14.76	97
98	97.05	13.64	96.99	14.06	96.92	14.49	96.86	14.91	98
99	98.04	13.78	97.98	14.21	97.91	14.63	97.85	15.06	99
100	99.03	13.92	98.97	14.35	98.90	14.78	98.84	15.21	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	82 Deg.		81¾ Deg.		81½ Deg.		81¼ Deg.		

Distance.	9 Deg.		9¼ Deg.		9½ Deg		9¾ Deg		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.99	0.16	0.99	0.16	0.99	0.17	0.99	0.17	1
2	1.98	0.31	1.97	0.32	1.97	0.33	1.97	0.34	2
3	2.96	0.47	2.96	0.48	2.96	0.50	2.96	0.51	3
4	3.95	0.63	3.95	0.64	3.95	0.66	3.94	0.68	4
5	4.94	0.78	4.93	0.80	4.93	0.83	4.93	0.85	5
6	5.93	0.94	5.92	0.96	5.92	0.99	5.91	1.02	6
7	6.91	1.10	6.91	1.13	6.90	1.16	6.90	1.19	7
8	7.90	1.25	7.90	1.29	7.89	1.32	7.88	1.35	8
9	8.89	1.41	8.88	1.45	8.88	1.49	8.87	1.52	9
10	9.88	1.56	9.87	1.61	9.86	1.65	9.86	1.69	10
11	10.86	1.72	10.86	1.77	10.85	1.82	10.84	1.86	11
12	11.85	1.88	11.84	1.93	11.84	1.98	11.83	2.03	12
13	12.84	2.03	12.83	2.09	12.82	2.15	12.81	2.20	13
14	13.83	2.19	13.82	2.25	13.81	2.31	13.80	2.37	14
15	14.82	2.35	14.80	2.41	14.79	2.48	14.78	2.54	15
16	15.80	2.50	15.79	2.57	15.78	2.64	15.77	2.71	16
17	16.79	2.66	16.78	2.73	16.77	2.81	16.75	2.88	17
18	17.78	2.82	17.77	2.89	17.75	2.97	17.74	3.05	18
19	18.77	2.97	18.75	3.05	18.74	3.14	18.73	3.22	19
20	19.75	3.13	19.74	3.21	19.73	3.30	19.71	3.39	20
21	20.74	3.29	20.73	3.38	20.71	3.47	20.70	3.56	21
22	21.73	3.44	21.71	3.54	21.70	3.63	21.68	3.73	22
23	22.72	3.60	22.70	3.70	22.68	3.80	22.67	3.90	23
24	23.70	3.75	23.69	3.86	23.67	3.96	23.65	4.06	24
25	24.69	3.91	24.67	4.02	24.66	4.13	24.64	4.23	25
26	25.68	4.07	25.66	4.18	25.64	4.29	25.62	4.40	26
27	26.67	4.22	26.65	4.34	26.63	4.46	26.61	4.57	27
28	27.66	4.38	27.64	4.50	27.62	4.62	27.60	4.74	28
29	28.64	4.54	28.62	4.66	28.60	4.79	28.58	4.91	29
30	29.63	4.69	29.61	4.82	29.59	4.95	29.57	5.08	30
31	30.62	4.85	30.60	4.98	30.57	5.12	30.55	5.25	31
32	31.61	5.01	31.58	5.14	31.56	5.28	31.54	5.42	32
33	32.59	5.16	32.57	5.30	32.55	5.45	32.52	5.59	33
34	33.58	5.32	33.56	5.47	33.53	5.61	33.51	5.76	34
35	34.57	5.48	34.54	5.63	34.52	5.78	34.49	5.93	35
36	35.56	5.63	35.53	5.79	35.51	5.94	35.48	6.10	36
37	36.54	5.79	36.52	5.95	36.49	6.11	36.47	6.27	37
38	37.53	5.94	37.51	6.11	37.48	6.27	37.45	6.44	38
39	38.52	6.10	38.49	6.27	38.47	6.44	38.44	6.60	39
40	39.51	6.26	39.48	6.43	39.45	6.60	39.42	6.77	40
41	40.50	6.41	40.47	6.59	40.44	6.77	40.41	6.94	41
42	41.48	6.57	41.45	6.75	41.42	6.92	41.39	7.11	42
43	42.47	6.73	42.44	6.91	42.41	7.10	42.38	7.28	43
44	43.46	6.88	43.43	7.07	43.40	7.26	43.36	7.45	44
45	44.45	7.04	44.41	7.23	44.38	7.43	44.35	7.62	45
46	45.43	7.20	45.40	7.39	45.37	7.59	45.34	7.79	46
47	46.42	7.35	46.39	7.55	46.36	7.76	46.32	7.96	47
48	47.41	7.51	47.38	7.72	47.34	7.92	47.31	8.13	48
49	48.40	7.67	48.36	7.88	48.33	8.09	48.29	8.30	49
50	49.38	7.82	49.35	8.04	49.32	8.25	49.28	8.47	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	81 Deg.		80¾ Deg.		80½ Deg.		80¼ Deg.		

Distance.	9 Deg.		9¼ Deg.		9½ Deg.		9¾ Deg		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	50.37	7.98	50.34	8.20	50.30	8.42	50.26	8.64	51
52	51.36	8.13	51.32	8.36	51.29	8.58	51.25	8.81	52
53	52.35	8.29	52.31	8.52	52.27	8.75	52.23	8.98	53
54	53.34	8.45	53.30	8.68	53.26	8.91	53.22	9.14	54
55	54.32	8.60	54.28	8.84	54.25	9.08	54.21	9.31	55
56	55.31	8.76	55.27	9.00	55.23	9.24	55.19	9.48	56
57	56.30	8.92	56.26	9.16	56.22	9.41	56.18	9.65	57
58	57.29	9.07	57.25	9.32	57.20	9.57	57.16	9.82	58
59	58.27	9.23	58.23	9.48	58.19	9.74	58.15	9.99	59
60	59.26	9.39	59.22	9.64	59.18	9.90	59.13	10.16	60
61	60.25	9.54	60.21	9.81	60.16	10.07	60.12	10.33	61
62	61.24	9.70	61.19	9.97	61.15	10.23	61.10	10.50	62
63	62.22	9.86	62.18	10.13	62.14	10.40	62.09	10.67	63
64	63.21	10.01	63.17	10.29	63.12	10.56	63.08	10.84	64
65	64.20	10.17	64.15	10.45	64.11	10.73	64.06	11.01	65
66	65.19	10.32	65.14	10.61	65.09	10.89	5.05	11.18	66
67	66.18	10.48	66.13	10.77	66.08	11.06	66.03	11.35	67
68	67.16	10.64	67.12	10.93	67.07	11.22	67.02	11.52	68
69	68.15	10.79	68.10	11.09	68.05	11.39	68.00	11.69	69
70	69.14	10.95	69.09	11.25	69.04	11.55	68.99	11.85	70
71	70.13	11.11	70.08	11.41	70.03	11.72	69.97	12.02	71
72	71.11	11.26	71.06	11.57	71.01	11.88	70.96	12.19	72
73	72.10	11.42	72.05	11.73	72.00	12.05	71.95	12.36	73
74	73.09	11.58	73.04	11.89	72.99	12.21	72.93	12.53	74
75	74.08	11.73	74.02	12.06	73.97	12.38	73.92	12.70	75
76	75.06	11.89	75.01	12.22	74.96	12.54	74.90	12.87	76
77	76.05	12.05	76.00	12.38	75.94	12.71	75.89	13.04	77
78	77.04	12.20	76.99	12.54	76.93	12.87	76.87	13.21	78
79	78.03	12.36	77.97	12.70	77.92	13.04	77.86	13.38	79
80	79.02	12.51	78.96	12.86	78.90	13.20	78.84	13.55	80
81	80.00	12.67	79.95	13.02	79.89	13.37	79.83	13.72	81
82	80.99	12.83	80.93	13.18	80.88	13.53	80.82	13.89	82
83	81.98	12.98	81.92	13.34	81.86	13.70	81.80	14.06	83
84	82.97	13.14	82.91	13.50	82.85	13.86	82.79	14.23	84
85	83.95	13.30	83.89	13.66	83.83	14.03	83.77	14.39	85
86	84.94	13.45	84.88	13.82	84.82	14.19	84.76	14.56	86
87	85.93	13.61	85.87	13.98	85.81	14.36	85.74	14.73	87
88	86.92	13.77	86.86	14.15	86.79	14.52	86.73	14.90	88
89	87.90	13.92	87.84	14.31	87.78	14.69	87.71	15.07	89
90	83.89	14.08	88.83	14.47	88.77	14.85	88.70	15.24	90
91	89.88	14.24	89.82	14.63	89.75	15.02	89.69	15.41	91
92	90.87	14.39	90.80	14.79	90.74	15.18	90.67	15.58	92
93	91.80	14.55	91.79	14.95	91.72	15.35	91.66	15.75	93
94	92.84	14.70	92.78	15.11	92.71	15.51	92.64	15.92	94
95	93.83	14.86	93.76	15.27	93.70	15.68	93.63	16.09	95
96	94.82	15.02	94.75	15.43	94.68	15.84	94.61	16.26	96
97	95.81	15.17	95.74	15.59	95.67	16.01	95.60	16.43	97
98	96.79	15.33	96.73	15.75	96.66	16.17	96.58	16.60	98
99	97.78	15.49	97.71	15.91	97.64	16.34	97.57	16.77	99
100	98.77	15.64	98.70	16.07	98.63	16.50	98.56	16.93	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat	Dep.	Lat.	Distance.
	81 Deg.		80¾ Deg.		80½ Deg		80¼ Deg.		

Distance.	10 Deg.		10¼ Deg.		10½ Deg.		10¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.98	0.17	0.98	0.18	0.98	0.18	0.98	0.19	1
2	1.97	0.35	1.97	0.36	1.97	0.36	1.96	0.37	2
3	2.95	0.52	2.95	0.53	2.95	0.55	2.95	0.56	3
4	3.94	0.69	3.94	0.71	3.93	0.73	3.93	0.75	4
5	4.92	0.87	4.92	0.89	4.92	0.91	4.91	0.93	5
6	5.91	1.04	5.90	1.07	5.90	1.09	5.89	1.12	6
7	6.89	1.22	6.89	1.25	6.88	1.28	6.88	1.31	7
8	7.88	1.39	7.87	1.42	7.87	1.46	7.86	1.49	8
9	8.86	1.56	8.86	1.60	8.85	1.64	8.84	1.68	9
10	9.85	1.74	9.84	1.78	9.83	1.82	9.82	1.87	10
11	10.83	1.91	10.82	1.96	10.82	2.00	10.81	2.05	11
12	11.82	2.08	11.81	2.14	11.80	2.19	11.79	2.24	12
13	12.80	2.26	12.79	2.31	12.78	2.37	12.77	2.42	13
14	13.79	2.43	13.78	2.49	13.77	2.55	13.75	2.61	14
15	14.77	2.60	14.76	2.67	14.75	2.73	14.74	2.80	15
16	15.76	2.78	15.74	2.85	15.73	2.92	15.72	2.98	16
17	16.74	2.95	16.73	3.03	16.72	3.10	16.70	3.17	17
18	17.73	3.13	17.71	3.20	17.70	3.28	17.68	3.36	18
19	18.71	3.30	18.70	3.38	18.68	3.46	18.67	3.54	19
20	19.70	3.47	19.68	3.56	19.67	3.64	19.65	3.73	20
21	20.68	3.65	20.66	3.74	20.65	3.83	20.63	3.92	21
22	21.67	3.82	21.65	3.91	21.63	4.01	21.61	4.10	22
23	22.65	3.99	22.63	4.09	22.61	4.19	22.60	4.29	23
24	23.64	4.17	23.62	4.27	23.60	4.37	23.58	4.48	24
25	24.62	4.34	24.60	4.45	24.58	4.56	24.56	4.66	25
26	25.61	4.51	25.59	4.63	25.56	4.74	25.54	4.85	26
27	26.59	4.69	26.57	4.80	26.55	4.92	26.53	5.04	27
28	27.57	4.86	27.55	4.98	27.53	5.10	27.51	5.22	28
29	28.56	5.04	28.54	5.16	28.51	5.28	28.49	5.41	29
30	29.54	5.21	29.52	5.34	29.50	5.47	29.47	5.60	30
31	30.53	5.38	30.51	5.52	30.48	5.65	30.46	5.78	31
32	31.51	5.56	31.49	5.69	31.46	5.83	31.44	5.97	32
33	32.50	5.73	32.47	5.87	32.45	6.01	32.42	6.16	33
34	33.48	5.90	33.46	6.05	33.43	6.20	33.40	6.34	34
35	34.47	6.08	34.44	6.23	34.41	6.38	34.39	6.53	35
36	35.45	6.25	35.43	6.41	35.40	6.56	35.37	6.71	36
37	36.44	6.42	36.41	6.58	36.38	6.74	36.35	6.90	37
38	37.42	6.60	37.39	6.76	37.36	6.92	37.33	7.09	38
39	38.41	6.77	38.38	6.94	38.35	7.11	38.32	7.27	39
40	39.39	6.95	39.36	7.12	39.33	7.29	39.30	7.46	40
41	40.38	7.12	40.35	7.30	40.31	7.47	40.28	7.65	41
42	41.36	7.29	41.33	7.47	41.30	7.65	41.26	7.83	42
43	42.35	7.47	42.31	7.65	42.28	7.84	42.25	8.02	43
44	43.33	7.64	43.30	7.83	43.26	8.02	43.23	8.21	44
45	44.32	7.81	44.28	8.01	44.25	8.20	44.21	8.39	45
46	45.30	7.99	45.27	8.19	45.23	8.38	45.19	8.58	46
47	46.29	8.16	46.25	8.36	46.21	8.57	46.18	8.77	47
48	47.27	8.34	47.23	8.54	47.20	8.75	47.16	8.95	48
49	48.26	8.51	48.22	8.72	48.18	8.93	48.14	9.11	49
50	49.24	8.68	49.20	8.90	49.16	9.11	49.12	9.33	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	80 Deg.		79¾ Deg.		79½ Deg.		79¼ Deg.		

Distance.	10 Deg.		10¼ Deg.		10½ Deg.		10¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep	
51	50.23	8.86	50.19	9.08	50.15	9.29	50.10	9.51	51
52	51.21	9.03	51.17	9.25	51.13	9.48	51.09	9.70	52
53	52.19	9.20	52.15	9.43	52.11	9.66	52.07	9.89	53
54	53.18	9.38	53.14	9.61	53.10	9.84	53.05	10.07	54
55	54.16	9.55	54.12	9.79	54.08	10.02	54.03	10.26	55
56	55.15	9.72	55.11	9.96	55.06	10.21	55.02	10.45	56
57	56.13	9.90	56.09	10.14	56.05	10.39	56.00	10.63	57
58	57.12	10.07	57.07	10.32	57.03	10.57	56.98	10.82	58
59	58.10	10.25	58.06	10.50	58.01	10.75	57.96	11.00	59
60	59.09	10.42	59.04	10.68	59.00	10.93	58.95	11.19	60
61	60.07	10.59	60.03	10.85	59.98	11.12	59.93	11.38	61
62	61.06	10.77	61.01	11.03	60.96	11.30	60.91	11.56	62
63	62.04	10.94	61.99	11.21	61.95	11.48	61.89	11.75	63
64	63.03	11.11	62.98	11.39	62.93	11.66	62.88	11.94	64
65	64.01	11.29	63.96	11.57	63.91	11.85	63.86	12.12	65
66	65.00	11.46	64.95	11.74	64.89	12.03	64.84	12.31	66
67	65.98	11.63	65.93	11.92	65.88	12.21	65.82	12.50	67
68	66.97	11.81	66.91	12.10	66.86	12.39	66.81	12.68	68
69	67.95	11.98	67.90	12.28	67.84	12.57	67.79	12.87	69
70	68.94	12.16	68.88	12.46	68.83	12.76	68.77	13.06	70
71	69.92	12.33	69.87	12.63	69.81	12.94	69.75	13.24	71
72	70.91	12.50	70.85	12.81	70.79	13.12	70.74	13.43	72
73	71.89	12.68	71.83	12.99	71.78	13.30	71.72	13.62	73
74	72.88	12.85	72.82	13.17	72.76	13.49	72.70	13.80	74
75	73.86	13.02	73.80	13.35	73.74	13.67	73.68	13.99	75
76	74.85	13.20	74.79	13.52	74.73	13.85	74.67	14.18	76
77	75.83	13.37	75.77	13.70	75.71	14.03	75.65	14.36	77
78	76.82	13.54	76.76	13.88	76.69	14.21	76.63	14.55	78
79	77.80	13.72	77.74	14.06	77.68	14.40	77.61	14.74	79
80	78.78	13.89	78.72	14.24	78.66	14.58	78.60	14.92	80
81	79.77	14.07	79.71	14.41	79.64	14.76	79.58	15.11	81
82	80.75	14.24	80.69	14.59	80.63	14.94	80.56	15.29	82
83	81.74	14.41	81.68	14.77	81.61	15.13	81.54	15.48	83
84	82.72	14.59	82.66	14.95	82.59	15.31	82.53	15.67	84
85	83.71	14.76	83.64	15.13	83.58	15.49	83.51	15.85	85
86	84.69	14.93	84.63	15.30	84.56	15.67	84.49	16.04	86
87	85.68	15.11	85.61	15.48	85.54	15.85	85.47	16.23	87
88	86.66	15.28	86.60	15.66	86.53	16.04	86.46	16.41	88
89	87.65	15.45	87.58	15.84	87.51	16.22	87.44	16.60	89
90	88.63	15.63	88.56	16.01	88.49	16.40	88.42	16.79	90
91	89.62	15.80	89.55	16.19	89.48	16.58	89.40	16.97	91
92	90.60	15.98	90.53	16.37	90.46	16.77	90.39	17.16	92
93	91.59	16.15	91.52	16.55	91.44	16.95	91.37	17.35	93
94	92.57	16.32	92.50	16.73	92.43	17.13	92.35	17.53	94
95	93.56	16.50	93.48	16.90	93.41	17.31	93.33	17.72	95
96	94.54	16.67	94.47	17.08	94.39	17.49	94.32	17.91	96
97	95.53	16.84	95.45	17.26	95.38	17.68	95.30	18.09	97
98	96.51	17.02	96.44	17.44	96.36	17.86	96.28	18.28	98
99	97.50	17.19	97.42	17.62	97.34	18.04	97.26	18.47	99
100	98.48	17.36	98.40	17.79	98.33	18.22	98.25	18.65	.00
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	80 Deg.		79¾ Deg.		79½ Deg.		79¼ Deg.		

Distance.	11 Deg.		11¼ Deg.		11½ Deg.		11¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.98	0.19	0.98	0.20	0.98	0.20	0.98	0.20	1
2	1.96	0.38	1.96	0.39	1.96	0.40	1.96	0.41	2
3	2.94	0.57	2.94	0.59	2.94	0.60	2.94	0.61	3
4	3.93	0.76	3.92	0.78	3.92	0.80	3.92	0.82	4
5	4.91	0.95	4.90	0.98	4.90	1.00	4.90	1.02	5
6	5.89	1.14	5.88	1.17	5.88	1.20	5.87	1.22	6
7	6.87	1.34	6.87	1.37	6.86	1.40	6.85	1.43	7
8	7.85	1.53	7.85	1.56	7.84	1.59	7.83	1.63	8
9	8.83	1.72	8.83	1.76	8.82	1.79	8.81	1.83	9
10	9.82	1.91	9.81	1.95	9.80	1.99	9.79	2.04	10
11	10.80	2.10	10.79	2.15	10.78	2.19	10.77	2.24	11
12	11.78	2.29	11.77	2.34	11.76	2.39	11.75	2.44	12
13	12.76	2.48	12.75	2.54	12.74	2.59	12.73	2.65	13
14	13.74	2.67	13.73	2.73	13.72	2.79	13.71	2.85	14
15	14.72	2.86	14.71	2.93	14.70	2.99	14.69	3.06	15
16	15.71	3.05	15.69	3.12	15.68	3.19	15.66	3.26	16
17	16.69	3.24	16.67	3.32	16.66	3.39	16.64	3.46	17
18	17.67	3.43	17.65	3.51	17.64	3.59	17.62	3.66	18
19	18.65	3.63	18.63	3.71	18.62	3.79	18.60	3.87	19
20	19.63	3.82	19.62	3.90	19.60	3.99	19.58	4.07	20
21	20.61	4.01	20.60	4.10	20.58	4.19	20.56	4.28	21
22	21.60	4.20	21.58	4.29	21.56	4.39	21.54	4.48	22
23	22.58	4.39	22.56	4.49	22.54	4.59	22.52	4.68	23
24	23.56	4.58	23.54	4.68	23.52	4.78	23.50	4.89	24
25	24.54	4.77	24.52	4.88	24.50	4.98	24.48	5.09	25
26	25.52	4.96	25.50	5.07	25.48	5.18	25.46	5.30	26
27	26.50	5.15	26.48	5.27	26.46	5.38	26.43	5.50	27
28	27.49	5.34	27.46	5.46	27.44	5.58	27.41	5.70	28
29	28.47	5.53	28.44	5.66	28.42	5.78	28.39	5.91	29
30	29.45	5.72	29.42	5.85	29.40	5.98	29.37	6.11	30
31	30.43	5.92	30.40	6.05	30.38	6.18	30.35	6.31	31
32	31.41	6.11	31.39	6.24	31.36	6.38	31.33	6.52	32
33	32.39	6.30	32.37	6.44	32.34	6.58	32.31	6.72	33
34	33.38	6.49	33.35	6.63	33.32	6.78	33.29	6.92	34
35	34.36	6.68	34.33	6.83	34.30	6.98	34.27	7.13	35
36	35.34	6.87	35.31	7.02	35.28	7.18	35.25	7.33	36
37	36.32	7.06	36.29	7.22	36.26	7.38	36.22	7.53	37
38	37.30	7.25	37.27	7.41	37.24	7.58	37.20	7.74	38
39	38.28	7.44	38.25	7.61	38.22	7.78	38.18	7.94	39
40	39.27	7.63	39.23	7.80	39.20	7.97	39.16	8.15	40
41	40.25	7.82	40.21	8.00	40.18	8.17	40.14	8.35	41
42	41.23	8.01	41.19	8.19	41.16	8.37	41.12	8.55	42
43	42.21	8.20	42.17	8.39	42.14	8.57	42.10	8.76	43
44	43.19	8.40	43.15	8.58	43.12	8.77	43.08	8.96	44
45	44.17	8.59	44.14	8.78	44.10	8.97	44.06	9.16	45
46	45.15	8.78	45.12	8.97	45.08	9.17	45.04	9.37	46
47	46.14	8.97	46.10	9.17	46.06	9.37	46.02	9.57	47
48	47.12	9.16	47.08	9.36	47.04	9.57	46.99	9.78	48
49	48.10	9.35	48.06	9.56	48.02	9.77	47.97	9.98	49
50	49.08	9.54	49.04	9.75	49.00	9.97	48.95	10.18	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	79 Deg		78¾ Deg.		8½ Deg.		78¼ Deg.		

Distance	11 Deg.		11¼ Deg.		11½ Deg.		11¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	50.06	9.73	50.02	9.95	49.98	10.17	49.93	10.39	51
52	51.04	9.92	51.06	10.14	50.96	10.37	50.91	10.59	52
53	52.03	10.11	51.98	10.34	51.94	10.57	51.89	10.79	53
54	53.01	10.30	52.96	10.53	52.92	10.77	52.87	11.00	54
55	53.99	10.49	53.94	10.73	53.90	10.97	53.85	11.20	55
56	54.97	10.69	54.92	10.93	54.88	11.16	54.83	11.40	56
57	55.95	10.88	55.90	11.12	55.86	11.36	55.81	11.61	57
58	56.93	11.07	56.89	11.32	56.84	11.56	56.78	11.81	58
59	57.92	11.26	57.87	11.51	57.82	11.76	57.76	12.01	59
60	58.90	11.45	58.85	11.71	58.80	11.96	58.74	12.22	60
61	59.88	11.64	59.83	11.90	59.78	12.16	59.72	12.42	61
62	60.86	11.83	60.81	12.10	60.76	12.36	60.70	12.63	62
63	61.84	12.02	61.79	12.29	61.74	12.56	61.68	12.83	63
64	62.82	12.21	62.77	12.49	62.72	12.76	62.66	13.03	64
65	63.81	12.40	63.75	12.68	63.70	12.96	63.64	13.24	65
66	64.79	12.59	64.73	12.88	64.68	13.16	64.62	13.44	66
67	65.77	12.78	65.71	13.07	65.66	13.36	65.60	13.64	67
68	66.75	12.98	66.69	13.27	66.63	13.56	66.58	13.85	68
69	67.73	13.17	67.67	13.46	67.61	13.76	67.55	14.05	69
70	68.71	13.36	68.66	13.66	68.59	13.96	68.53	14.25	70
71	69.70	13.55	69.64	13.85	69.57	14.16	69.51	14.46	71
72	70.68	13.74	70.62	14.05	70.55	14.35	70.49	14.66	72
73	71.66	13.93	71.60	14.24	71.53	14.55	71.47	14.87	73
74	72.64	14.12	72.58	14.44	72.51	14.75	72.45	15.07	74
75	73.62	14.31	73.56	14.63	73.49	14.95	73.43	15.27	75
76	74.60	14.50	74.54	14.83	74.47	15.15	74.41	15.48	76
77	75.59	14.69	75.52	15.02	75.45	15.35	75.39	15.68	77
78	76.57	14.88	76.50	15.22	76.43	15.55	76.37	15.88	78
79	77.55	15.07	77.48	15.41	77.41	15.75	77.34	16.09	79
80	78.53	15.26	78.46	15.61	78.39	15.95	78.32	16.29	80
81	79.51	15.46	79.44	15.80	79.37	16.15	79.30	16.49	81
82	80.49	15.65	80.42	16.00	80.35	16.35	80.28	16.70	82
83	81.48	15.84	81.41	16.19	81.33	16.55	81.26	16.90	83
84	82.46	16.03	82.39	16.39	82.31	16.75	82.24	17.11	84
85	83.44	16.22	83.37	16.58	83.29	16.95	83.22	17.31	85
86	84.42	16.41	84.35	16.78	84.27	17.15	84.20	17.51	86
87	85.40	16.60	85.33	16.97	85.25	17.35	85.18	17.72	87
88	86.38	16.79	86.31	17.17	86.23	17.54	86.16	17.92	88
89	87.36	16.98	87.29	17.36	87.21	17.74	87.14	18.12	89
90	88.35	17.17	88.27	17.56	88.19	17.94	88.11	18.33	90
91	89.33	17.36	89.25	17.75	89.17	18.14	89.09	18.53	91
92	90.31	17.55	90.23	17.95	90.15	18.34	90.07	18.74	92
93	91.29	17.75	91.21	18.14	91.13	18.54	91.05	18.94	93
94	92.27	17.94	92.19	18.34	92.11	18.74	92.03	19.14	94
95	93.25	18.13	93.17	18.53	93.09	18.94	93.01	19.35	95
96	94.24	18.32	94.16	18.73	94.07	19.14	93.99	19.55	96
97	95.22	18.51	95.14	18.92	95.05	19.34	94.97	19.75	97
98	96.20	18.70	96.12	19.12	96.03	19.54	95.95	19.96	98
99	97.18	18.89	97.10	19.31	97.01	19.74	96.93	20.16	99
100	98.16	19.08	98.08	19.51	97.99	19.94	97.90	20.36	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	79 Deg.		78¾ Deg.		78½ Deg.		78¼ Deg.		

Distance.	12 Deg		12¼ Deg.		12½ Deg.		12¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep	
1	0.98	0.21	0.98	0.21	0.98	0.22	0.98	0.22	1
2	1.96	0.42	1.95	0.42	1.95	0.43	1.95	0.44	2
3	2.93	0.62	2.93	0.64	2.93	0.65	2.93	0.66	3
4	3.91	0.83	3.91	0.85	3.91	0.87	3.90	0.88	4
5	4.89	1.04	4.89	1.06	4.88	1.08	4.88	1.10	5
6	5.87	1.25	5.86	1.27	5.86	1.30	5.85	1.32	6
7	6.85	1.46	6.84	1.49	6.83	1.52	6.83	1.54	7
8	7.83	1.66	7.82	1.70	7.81	1.73	7.80	1.77	8
9	8.80	1.87	8.80	1.91	8.79	1.95	8.78	1.99	9
10	9.78	2.08	9.77	2.12	9.76	2.16	9.75	2.21	10
11	10.76	2.29	10.75	2.33	10.74	2.38	10.73	2.43	11
12	11.74	2.49	11.73	2.55	11.72	2.60	11.70	2.65	12
13	12.72	2.70	12.70	2.76	12.69	2.81	12.68	2.87	13
14	13.69	2.91	13.68	2.97	13.67	3.03	13.65	3.09	14
15	14.67	3.12	14.66	3.18	14.64	3.25	14.63	3.31	15
16	15.65	3.33	15.64	3.39	15.62	3.46	15.61	3.53	16
17	16.63	3.53	16.61	3.61	16.60	3.68	16.58	3.75	17
18	17.61	3.74	17.59	3.82	17.57	3.90	17.56	3.97	18
19	18.58	3.95	18.57	4.03	18.55	4.11	18.53	4.19	19
20	19.56	4.16	19.54	4.24	19.53	4.33	19.51	4.41	20
21	20.54	4.37	20.52	4.46	20.50	4.55	20.48	4.63	21
22	21.52	4.57	21.50	4.67	21.48	4.76	21.46	4.86	22
23	22.50	4.78	22.48	4.88	22.45	4.98	22.43	5.08	23
24	23.48	4.99	23.45	5.09	23.43	5.19	23.41	5.30	24
25	24.45	5.20	24.43	5.30	24.41	5.41	24.38	5.52	25
26	25.43	5.41	25.41	5.52	25.38	5.63	25.36	5.74	26
27	26.41	5.61	26.39	5.73	26.36	5.84	26.33	5.96	27
28	27.39	5.82	27.36	5.94	27.34	6.06	27.31	6.18	28
29	28.37	6.03	28.34	6.15	28.31	6.28	28.28	6.40	29
30	29.34	6.24	29.32	6.37	29.29	6.49	29.26	6.62	30
31	30.32	6.45	30.29	6.58	30.27	6.71	30.24	6.84	31
32	31.30	6.65	31.27	6.79	31.24	6.93	31.21	7.06	32
33	32.28	6.86	32.25	7.00	32.22	7.14	32.19	7.28	33
34	33.26	7.07	33.23	7.21	33.19	7.36	33.16	7.50	34
35	34.24	7.28	34.20	7.43	34.17	7.58	34.14	7.72	35
36	35.21	7.48	35.18	7.64	35.15	7.79	35.11	7.95	36
37	36.19	7.69	36.16	7.85	36.12	8.01	36.09	8.17	37
38	37.17	7.90	37.13	8.06	37.10	8.22	37.06	8.39	38
39	38.15	8.11	38.11	8.27	38.08	8.44	38.04	8.61	39
40	39.13	8.32	39.09	8.49	39.05	8.66	39.01	8.83	40
41	40.10	8.52	40.07	8.70	40.03	8.87	39.99	9.05	41
42	41.08	8.73	41.04	8.91	41.00	9.09	40.96	9.27	42
43	42.06	8.94	42.02	9.12	41.98	9.3.	41.94	9.49	43
44	43.04	9.15	43.00	9.34	42.96	9.52	42.92	9.71	44
45	44.02	9.36	43.98	9.55	43.93	9.74	43.89	9.93	45
46	44.99	9.56	44.95	9.76	44.91	9.96	44.87	10.15	46
47	45.97	9.77	45.93	9.97	45.89	10.17	45.84	10.37	47
48	46.95	9.98	46.91	10.18	46.86	10.29	46.82	10.59	48
49	47.93	10.19	47.88	10.40	47.84	10.61	47.79	10.81	49
50	48.91	10.40	48.86	10.61	48.81	10.82	48.77	11.03	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	78 Deg		77¾ Deg.		77½ Deg.		77¼ Deg.		

Distance.	12 Deg.		12¼ Deg.		12½ Deg.		12¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	49.89	10.60	49.84	10.82	49.79	11.04	49.74	11.26	51
52	50.86	10.81	50.82	11.03	50.77	11.25	50.72	11.48	52
53	51.84	11.02	51.79	11.25	51.74	11.47	51.69	11.70	53
54	52.82	11.23	52.77	11.46	52.72	11.69	52.67	11.92	54
55	53.80	11.44	53.75	11.67	53.70	11.90	53.64	12.14	55
56	54.78	11.64	54.72	11.88	54.67	12.12	54.62	12.36	56
57	55.75	11.85	55.70	12.09	55.65	12.34	55.59	12.58	57
58	56.73	12.06	56.68	12.31	56.63	12.55	56.57	12.80	58
59	57.71	12.27	57.66	12.52	57.60	12.77	57.55	13.02	59
60	58.69	12.47	58.63	12.73	58.58	12.99	58.52	13.24	60
61	59.67	12.68	59.61	12.94	59.55	13.20	59.50	13.46	61
62	60.65	12.89	60.59	13.16	60.53	13.42	60.47	13.68	62
63	61.62	13.10	61.57	13.37	61.51	13.64	61.45	13.90	63
64	62.60	13.31	62.54	13.58	62.48	13.85	62.42	14.12	64
65	63.58	13.51	63.52	13.79	63.46	14.07	63.40	14.35	65
66	64.56	13.72	64.50	14.00	64.44	14.29	64.37	14.57	66
67	65.54	13.93	65.47	14.22	65.41	14.50	65.35	14.79	67
68	66.51	14.14	66.45	14.43	66.39	14.72	66.32	15.01	68
69	67.49	14.35	67.43	14.64	67.36	14.93	67.30	15.23	69
70	68.47	14.55	68.41	14.85	68.34	15.15	68.27	15.45	70
71	69.45	14.76	69.38	15.06	69.32	15.37	69.25	15.67	71
72	70.43	14.97	70.36	15.28	70.29	15.58	70.22	15.89	72
73	71.40	15.18	71.34	15.49	71.27	15.80	71.20	16.11	73
74	72.38	15.39	72.32	15.70	72.25	16.02	72.18	16.33	74
75	73.36	15.59	73.29	15.91	73.22	16.23	73.15	16.55	75
76	74.34	15.80	74.27	16.13	74.20	16.45	74.13	16.77	76
77	75.32	16.01	75.25	16.34	75.17	16.67	75.10	16.99	77
78	76.30	16.22	76.22	16.55	76.15	16.88	76.08	17.21	78
79	77.27	16.43	77.20	16.76	77.13	17.10	77.05	17.44	79
80	78.25	16.63	78.18	16.97	78.10	17.32	78.03	17.66	80
81	79.23	16.84	79.16	17.19	79.08	17.53	79.00	17.88	81
82	80.21	17.05	80.13	17.40	80.06	17.75	79.98	18.10	82
83	81.19	17.26	81.11	17.61	81.03	17.96	80.95	18.32	83
84	82.16	17.46	82.09	17.82	82.01	18.18	81.93	18.54	84
85	83.14	17.67	83.06	18.04	82.99	18.40	82.90	18.76	85
86	84.12	17.88	84.04	18.25	83.96	18.61	83.88	18.98	86
87	85.10	18.09	85.02	18.46	84.94	18.83	84.85	19.20	87
88	86.08	18.30	86.00	18.67	85.91	19.05	85.83	19.42	88
89	87.06	18.50	86.97	18.88	86.89	19.26	86.81	19.64	89
90	88.03	18.71	87.95	19.10	87.87	19.48	87.78	19.86	90
91	89.01	18.92	88.93	19.31	88.84	19.70	88.76	20.08	91
92	89.99	19.13	89.91	19.52	89.82	19.91	89.72	20.30	92
93	90.97	19.34	90.88	19.73	90.80	20.13	90.71	20.52	93
94	91.95	19.54	91.86	19.94	91.77	20.35	91.68	20.75	94
95	92.92	19.75	92.84	20.16	92.75	20.56	92.66	20.97	95
96	93.90	19.96	93.81	20.37	93.72	20.78	93.63	21.19	96
97	94.88	20.17	94.79	20.58	94.70	20.99	94.61	21.41	97
98	95.86	20.38	95.77	20.79	95.68	21.21	95.58	21.63	98
99	96.84	20.58	96.75	21.01	96.65	21.43	96.56	21.85	99
100	97.81	20.79	97.72	21.22	97.63	21.64	97.53	22.07	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	78 Deg.		77¾ Deg		77½ Deg.		77¼ Deg.		

Distance.	14 Deg.		14¼ Deg.		14½ Deg.		14¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.97	0.24	0.97	0.25	0.97	0.25	0.97	0.25	1
2	1.94	0.48	1.94	0.49	1.94	0.50	1.93	0.51	2
3	2.91	0.73	2.91	0.74	2.90	0.75	2.90	0.76	3
4	3.88	0.97	3.88	0.98	3.87	1.00	2.87	1.02	4
5	4.85	1.21	4.85	1.23	4.84	1.25	4.84	1.27	5
6	5.82	1.45	5.82	1.48	5.81	1.50	5.80	1.53	6
7	6.79	1.69	6.78	1.72	6.78	1.75	6.77	1.78	7
8	7.76	1.94	7.75	1.97	7.75	2.00	7.74	2.04	8
9	8.73	2.18	8.72	2.22	8.71	2.25	8.70	2.29	9
10	9.70	2.42	9.69	2.46	9.68	2.50	9.67	2.55	10
11	10.67	2.66	10.66	2.71	10.65	2.75	10.64	2.80	11
12	11.64	2.90	11.63	2.95	11.62	3.00	11.60	3.06	12
13	12.61	3.15	12.60	3.20	12.59	3.25	12.57	3.31	13
14	13.58	3.39	13.57	3.45	13.55	3.51	13.54	3.56	14
15	14.55	3.63	14.54	3.69	14.52	3.76	14.51	3.82	15
16	15.52	3.87	15.51	3.94	15.49	4.01	15.47	4.07	16
17	16.50	4.11	16.48	4.18	16.46	4.26	16.44	4.33	17
18	17.47	4.35	17.45	4.43	17.43	4.51	17.41	4.58	18
19	18.44	4.60	18.42	4.68	18.39	4.76	18.37	4.84	19
20	19.41	4.84	19.38	4.92	19.36	5.01	19.34	5.09	20
21	20.38	5.08	20.35	5.17	20.33	5.26	20.31	5.35	21
22	21.35	5.32	21.32	5.42	21.30	5.51	21.28	5.60	22
23	22.32	5.56	22.29	5.66	22.27	5.76	22.24	5.86	23
24	23.29	5.81	23.26	5.91	23.24	6.01	23.21	6.11	24
25	24.26	6.05	24.23	6.15	24.20	6.26	24.18	6.37	25
26	25.23	6.29	25.20	6.40	25.17	6.51	25.14	6.62	26
27	26.20	6.53	26.17	6.65	26.14	6.76	26.11	6.87	27
28	27.17	6.77	27.14	6.89	27.11	7.01	27.08	7.13	28
29	28.14	7.02	28.11	7.14	28.08	7.26	28.04	7.38	29
30	29.11	7.26	29.08	7.38	29.04	7.51	29.01	7.64	30
31	30.08	7.50	30.05	7.63	30.01	7.76	29.98	7.89	31
32	31.05	7.74	31.02	7.88	30.98	8.01	30.95	8.15	32
33	32.02	7.98	31.98	8.12	31.95	8.26	31.91	8.40	33
34	32.99	8.23	32.95	8.37	32.92	8.51	32.88	8.66	34
35	33.96	8.47	33.92	8.62	33.89	8.76	33.85	8.91	35
36	34.93	8.71	34.89	8.86	34.85	9.01	34.81	9.17	36
37	35.90	8.95	35.86	9.11	35.82	9.26	35.78	9.42	37
38	36.87	9.19	36.83	9.35	36.79	9.51	36.75	9.67	38
39	37.84	9.44	37.80	9.60	37.76	9.76	37.71	9.93	39
40	38.81	9.68	38.77	9.85	38.73	10.02	38.68	10.18	40
41	39.78	9.92	39.74	10.09	39.69	10.27	39.65	10.44	41
42	40.75	10.16	40.71	10.34	40.66	10.52	40.62	10.69	42
43	41.72	10.40	41.68	10.58	41.63	10.77	41.58	10.95	43
44	42.69	10.64	42.65	10.83	42.60	11.02	42.55	11.20	44
45	43.66	10.89	43.62	11.08	43.57	11.27	43.52	11.46	45
46	44.63	11.13	44.58	11.32	44.53	11.52	44.48	11.71	46
47	45.60	11.37	45.55	11.57	45.50	11.77	45.45	11.97	47
48	46.57	11.61	46.52	11.82	46.47	12.02	46.42	12.22	48
49	47.54	11.85	47.49	12.06	47.44	12.27	47.39	12.48	49
50	48.51	12.10	48.46	12.31	48.41	12.52	48.35	12.73	50
Distance.	Dep	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	76 Deg.		75¾ Deg.		75½ Deg.		75¼ Deg.		

Distance.	14 Deg.		14¼ Deg.		14½ Deg.		14¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	49.49	12.34	49.43	12.55	49.38	12.77	49.32	12.98	51
52	50.46	12.58	50.40	12.80	50.34	13.02	50.29	13.24	52
53	51.43	12.82	51.37	13.05	51.31	13.27	51.25	13.49	53
54	52.40	13.06	52.34	13.29	52.28	13.52	52.22	13.75	54
55	53.37	13.31	53.31	13.54	53.25	13.77	53.19	14.00	55
56	54.34	13.55	54.28	13.78	54.22	14.02	54.15	14.26	56
57	55.31	13.79	55.25	14.03	55.18	14.27	55.12	14.51	57
58	56.28	14.03	56.22	14.28	56.15	14.52	56.09	14.77	58
59	57.25	14.27	57.18	14.52	57.12	14.77	57.06	15.02	59
60	58.22	14.52	58.15	14.77	58.09	15.02	58.02	15.28	60
61	59.19	14.76	59.12	15.02	59.06	15.27	58.99	15.53	61
62	60.16	15.00	60.09	15.26	60.03	15.52	59.96	15.79	62
63	61.13	15.24	61.06	15.51	60.99	15.77	60.92	16.04	63
64	62.10	15.48	62.03	15.75	61.96	16.02	61.89	16.29	64
65	63.07	15.72	63.00	16.00	62.93	16.27	62.86	16.55	65
66	64.04	15.97	63.97	16.25	63.90	16.53	63.83	16.80	66
67	65.01	16.21	64.94	16.49	64.87	16.78	64.79	17.06	67
68	65.98	16.45	65.91	16.74	65.83	17.03	65.76	17.31	68
69	66.95	16.69	66.88	16.98	66.80	17.28	66.73	17.57	69
70	67.92	16.93	67.85	17.23	67.77	17.53	67.69	17.82	70
71	68.89	17.18	68.82	17.48	68.74	17.78	68.66	18.08	71
72	69.86	17.42	69.78	17.72	69.71	18.03	69.63	18.33	72
73	70.83	17.66	70.75	17.97	70.67	18.28	70.59	18.59	73
74	71.80	17.90	71.72	18.22	71.64	18.53	71.56	18.84	74
75	72.77	18.14	72.69	18.46	72.61	18.78	72.53	19.10	75
76	73.74	18.39	73.66	18.71	73.58	19.03	73.50	19.35	76
77	74.71	18.63	74.63	18.95	74.55	19.28	74.46	19.60	77
78	75.68	18.87	75.60	19.20	75.52	19.53	75.43	19.86	78
79	76.65	19.11	76.57	19.45	76.48	19.78	76.40	20.11	79
80	77.62	19.35	77.54	19.69	77.45	20.03	77.36	20.37	80
81	78.59	19.60	78.51	19.94	78.42	20.28	78.33	20.62	81
82	79.56	19.84	79.48	20.18	79.39	20.53	79.30	20.88	82
83	80.53	20.08	80.45	20.43	80.36	20.78	80.26	21.13	83
84	81.50	20.32	81.42	20.68	81.32	21.03	81.23	21.39	84
85	82.48	20.56	82.38	20.92	82.29	21.28	82.20	21.64	85
86	83.45	20.81	83.35	21.17	83.26	21.53	83.17	21.90	86
87	84.42	21.05	84.32	21.42	84.23	21.78	84.13	22.15	87
88	85.39	21.29	85.29	21.66	85.20	22.03	85.10	22.41	88
89	86.36	21.53	86.26	21.91	86.17	22.28	86.07	22.66	89
90	87.33	21.77	87.23	22.15	87.13	22.53	87.03	22.91	90
91	88.30	22.01	88.20	22.40	88.10	22.78	88.00	23.17	91
92	89.27	22.26	89.17	22.65	89.07	23.04	88.97	23.42	92
93	90.24	22.50	90.14	22.89	90.04	23.29	89.94	23.68	93
94	91.21	22.74	91.11	23.14	91.01	23.54	90.90	23.93	94
95	92.18	22.98	92.08	23.38	91.97	23.79	91.87	24.19	95
96	93.15	23.22	93.05	23.63	92.94	24.04	92.84	24.44	96
97	94.12	23.47	94.02	23.88	93.91	24.29	93.80	24.70	97
98	95.09	23.71	94.98	24.12	94.88	24.54	94.77	24.95	98
99	96.06	23.95	95.95	24.37	95.85	24.79	95.74	25.21	99
100	97.03	24.19	96.92	24.62	96.81	25.04	96.70	25.46	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	76 Deg.		75¾ Deg		75½ Deg.		75¼ Deg		

Distance.	15 Deg.		15¼ Deg.		15½ Deg.		15¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.97	0.26	0.96	0.26	0.96	0.27	0.96	0.27	1
2	1.93	0.52	1.93	0.53	1.93	0.53	1.92	0.54	2
3	2.90	0.78	2.89	0.79	2.89	0.80	2.89	0.81	3
4	3.86	1.04	3.86	1.05	3.85	1.07	3.85	1.09	4
5	4.83	1.29	4.82	1.32	4.82	1.34	4.81	1.36	5
6	5.80	1.55	5.79	1.58	5.78	1.60	5.77	1.63	6
7	6.76	1.81	6.75	1.84	6.75	1.87	6.74	1.90	7
8	7 73	2.07	7.72	2.10	7.71	2.14	7.70	2.17	8
9	8.69	2.33	8.68	2.37	8.67	2.41	8.66	2.44	9
10	9.66	2.59	9.65	2.63	9.64	2.67	9.62	2.71	10
11	10.63	2.85	10.61	2.89	10.60	2.94	10.59	2.99	11
12	11.59	3.11	11.58	3.16	11.56	3.21	11.55	3.26	12
13	12.56	3.36	12.54	3.42	12.53	3.47	12.51	3.53	13
14	13.52	3.62	13.51	3.68	13.49	3.74	13.47	3.80	14
15	14.49	3.88	14.47	3.95	14.45	4.01	14.44	4.07	15
16	15.45	4.14	15.44	4.21	15.42	4.28	15.40	4.34	16
17	16.42	4.40	16.40	4.47	16.38	4.54	16.36	4.61	17
18	17.39	4.66	17.37	4.73	17.35	4.81	17.32	4.89	18
19	18.35	4.92	18.33	5.00	18.31	5.08	18.29	5.16	19
20	19.32	5.18	19.30	5.26	19.27	5.34	19.25	5.43	20
21	20.28	5.44	20.26	5.52	20.24	5.61	20.21	5.70	21
22	21.25	5.69	21.23	5.79	21.20	5.88	21.17	5.97	22
23	22.22	5.95	22.19	6.05	22.16	6.15	22.14	6.24	23
24	23.18	6.21	23.15	6.31	23.13	6.41	23.10	6.51	24
25	24.15	6.47	24.12	6.58	24.09	6.68	24.06	6.79	25
26	25.11	6.73	25.08	6.84	25.05	6.95	25.02	7.06	26
27	26.08	6.99	26.05	7.10	26.02	7.22	25.99	7.33	27
28	27.05	7.25	27.01	7.36	26.98	7.48	26.95	7.60	28
29	28.01	7.51	27.98	7.63	27.95	7.75	27.91	7.87	29
30	28.98	7.76	28.94	7.89	28.91	8.02	28.87	8.14	30
31	29.94	8.02	29.91	8.15	29.87	8.28	29.84	8.41	31
32	30.91	8.28	30.87	8.42	30.84	8.55	30.80	8.69	32
33	31.88	8.54	31.84	8.68	31.80	8.82	31.76	8.96	33
34	32.84	8.80	32.80	8.94	32.76	9.09	32.72	9.23	34
35	33.81	9.06	33.77	9.21	33.73	9.35	33.69	9.50	35
36	34.77	9.32	34.73	9.47	34.69	9.62	34.65	9.77	36
37	35.74	9.58	35.70	9.73	35.65	9.89	35.61	10.04	37
38	36.71	9.84	36.66	10.00	36.62	10.16	36.57	10.31	38
39	37.67	10.09	37.63	10.26	37.58	10.42	37.54	10.59	39
40	38.64	10.35	38.59	10.52	38.55	10.69	38.50	10.86	40
41	39.60	10.61	39.56	10.78	39.51	10.96	39.46	11.13	41
42	40.57	10.87	40.52	11.05	40.47	11.22	40.42	11.40	42
43	41.53	11.13	41.49	11.31	41.44	11.49	41.39	11.67	43
44	42.50	11.39	42.45	11.57	42.40	11.76	42.35	11.94	44
45	43.47	11.65	43.42	11.84	43.36	12.03	43.31	12.21	45
46	44.43	11.91	44.38	12.10	44.33	12.29	44.27	12.49	46
47	45.40	12.16	45 35	12.36	45.29	12.56	45.24	12.76	47
48	46.36	12.42	46.31	12.63	46.25	12.83	46.20	13.03	48
49	47.33	12.68	47.27	12.89	47.22	13.09	47.16	13.30	49
50	48.30	12.94	48.24	13.15	48.18	13.36	48.12	13.57	50
Distance.	Dep.	Lat.	Dep.	Lat	Dep.	Lat.	Dep.	Lat.	Distance.
	75 Deg.		74¾ Deg.		74½ Deg.		74¼ Deg.		

Distance.	15 Deg.		15¼ Deg		15½ Deg.		15¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	49.26	13.20	49.20	13.41	49.15	13.63	49.09	13.84	51
52	50.23	13.46	50.17	13.68	50.11	13.90	50.05	14.11	52
53	51.19	13.72	51.13	13.94	51.07	14.16	51.01	11.39	53
54	52.16	13.98	52.10	14.20	52.04	14.43	51 97	14.66	54
55	53.12	14.24	53.06	14.47	53.00	14.70	52.94	14.93	55
56	54.09	14.49	54.03	14.73	53.96	14.97	53.90	15.20	56
57	55.06	14.75	54.99	14.99	54.93	15.23	54.86	15.47	57
58	56.02	15.01	55.96	15.26	55.89	15.50	55.82	15.74	58
59	56.99	15.27	56.92	15.52	56.85	15.77	56.78	16.01	59
60	57.96	15.53	57.89	15.78	57.82	16.03	57.75	16.29	60
61	58.92	15.79	58.85	16.04	58.78	16.30	58.71	16.56	61
62	59.89	16.05	59.82	16.31	59.75	16.57	59.67	16.83	62
63	60.85	16.31	60.78	16.57	60.71	16.84	60.63	17.10	63
64	61.82	16.56	61.75	16.83	61.67	17.10	61.60	17.37	64
65	62.79	16.82	62.71	17.10	62.64	17.37	62.56	17.64	65
66	63.75	17.08	63.68	17.35	63.60	17.64	63.52	17.92	66
67	64.72	17.34	64.64	17.62	64.56	17.90	64.48	18.19	67
68	65.68	17.60	65.61	17.89	65.53	18.17	65.45	18.46	68
69	66.65	17.86	66.57	18.15	66.49	18.44	66.41	18.73	69
70	67.61	18.12	67.54	18.41	67.45	18.71	67.37	19.00	70
71	68.58	18.38	68.50	18.68	68.42	18.97	68.33	19.27	71
72	69.55	18.63	69.46	18.94	69.38	19.24	69.30	19.54	72
73	70.51	18.89	70.43	19.20	70.35	19.51	70.26	19.82	73
74	71.48	19.15	71.39	19.46	71.31	19.78	71.22	20.09	74
75	72.44	19.41	72.36	19.73	72.27	20.04	72.18	20.36	75
76	73.41	19.67	73.32	19.99	73.24	20.31	73.15	20.63	76
77	74.38	19.93	74.29	20.25	74.20	20.58	74.11	20.90	77
78	75.34	20.19	75.25	20.52	75.16	20.84	75.07	21.17	78
79	76.31	20.45	76.22	20.78	76.13	21.11	76.03	21.44	79
80	77.27	20.71	77.18	21.04	77.09	21.38	77.00	21.72	80
81	78.24	20.96	78.15	21.31	78.05	21.65	77.96	21.99	81
82	79.21	21.22	79.11	21.57	79.02	21.91	78.92	22.26	82
83	80.17	21.48	80.08	21.83	79.98	22.18	79.88	22.53	83
84	81.14	21.74	81.04	22.09	80.94	22.45	80.85	22.80	84
85	82.10	22.00	82.01	22.36	81.91	22.72	81.81	23.07	85
86	83.07	22.26	82.97	22.62	82.87	22.98	82.77	23.34	86
87	84.04	22.52	83.94	22.88	83.84	23.25	83.73	23.62	87
88	85.00	22.78	84.90	23.15	84.80	23.52	84.70	23.89	88
89	85.97	23.03	85.87	23.41	85.76	23.78	85.66	24.16	89
90	86.93	23.29	86.83	23.67	86.73	24.05	86.62	24.43	90
91	87.90	23.55	87.80	23.94	87.69	24.32	87.58	24.70	91
92	88.87	23.81	88.76	24.20	88.65	24.59	88.55	24.97	92
93	89.83	24.07	89.73	24.46	89.62	24.85	89.51	25.24	93
94	90.80	24.33	90.69	24.72	90.58	25.12	90.47	25.52	94
95	91.76	24.59	91.65	24.99	91 34	25.39	91.43	25.79	95
96	92 73	24.85	92.62	25.25	92.51	25.65	92.40	26.06	96
97	93.69	25.11	93.58	25.51	93.47	25.92	93.36	26.33	97
98	94.66	25.36	94.55	25.78	94.44	26.19	94.32	26.60	98
99	95.63	25.62	95.51	26.04	95.40	26.46	95.28	26.87	99
100	96.59	25.88	36.48	26.30	96.36	26.72	96.25	27.14	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	75 Deg.		74¾ Deg.		74½ Deg.		74¼ Deg.		

Distance.	16 Deg.		16¼ Deg.		16½ Deg.		16¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.96	0.28	0.96	0.28	0.96	0 28	0.96	0.29	1
2	1 92	0 55	1.92	0.56	1.92	0.57	1.92	0.58	2
3	2.88	0 83	2.88	0.84	2.88	0.85	2.87	0.86	3
4	3.85	1.10	3.84	1.12	3.84	1.14	3.83	1.15	4
5	4.81	1.38	4.80	1.40	4.79	1.42	4.79	1.44	5
6	5.77	1.65	5.76	1.68	5.75	1.70	5.75	1.73	6
7	6.73	1.93	6.72	1.96	6.71	1.99	6.70	2.02	7
8	7.69	2.21	7.68	2.24	7.67	2.27	7.66	2.31	8
9	8.65	2.48	8.64	2.52	8.63	2.56	8.62	2.59	9
10	9.61	2.76	9.60	2.80	9.59	2.84	9.58	2.88	10
11	10.57	3.03	10.56	3.08	10.55	3.12	10.53	3.17	11
12	11.54	3.31	11.52	3.36	11.51	3.41	11.49	3.46	12
13	12.50	3.58	12.48	3.64	12.46	3.69	12.45	3.75	13
14	13.46	3.86	13.44	3.92	13.42	3.98	13.41	4.03	14
15	14.42	4.13	14.40	4.20	14.38	4.26	14.36	4.32	15
16	15.38	4.41	15.36	4.48	15.34	4.54	15.32	4.61	16
17	16.34	4.69	16.32	4.76	16.30	4.83	16.28	4.90	17
18	17.30	4.96	17.28	5.04	17.26	5.11	17.24	5.19	18
19	18.26	5.24	18.24	5.32	18.22	5.40	18.19	5.48	19
20	19.23	5.51	19.20	5.60	19.18	5.68	19.15	5.76	20
21	20.19	5.79	20.16	5.88	20.14	5.96	20.11	6.05	21
22	21.15	6.06	21.12	6.16	21.09	6.25	21.07	6.34	22
23	22.11	6.34	22.08	6.44	22.05	6.53	22.02	6.63	23
24	23.07	6.62	23.04	6.72	23.01	6.82	22.98	6.92	24
25	24.03	6.89	24.00	7.00	23.97	7.10	23.94	7.20	25
26	24.99	7.17	24.96	7.28	24.93	7.38	24.90	7.49	26
27	25.95	7.44	25.92	7.56	25.89	7.67	25.85	7.78	27
28	26.92	7.72	26.88	7.84	26.85	7.95	26.81	8.07	28
29	27.88	7.99	27.84	8.11	27.81	8.24	27.77	8.36	29
30	28.84	8.27	28.80	8.39	28.76	8.52	28.73	8.65	30
31	29.80	8.54	29.76	8.67	29.72	8.80	29.68	8.93	31
32	30.76	8.82	30.72	8.95	30.68	9.09	30.64	9.22	32
33	31.72	9.10	31.68	9.23	31.64	9.37	31.60	9.51	33
34	32.68	9.37	32.64	9.51	32.60	9.66	32.56	9.80	34
35	33.64	9.65	33.60	9.79	33.56	9.94	33.51	10.09	35
36	34.61	9.92	34.56	10.07	34.52	10.22	34.47	10.38	36
37	35.57	10.20	35 52	10.35	35.48	10.51	35.43	10.66	37
38	36.53	10.47	36.48	10.63	36.44	10.79	36.39	10.95	38
39	37.49	10.75	37.44	10.91	37.39	11.08	37.35	11.24	39
40	38.45	11.03	38.40	11.19	38.35	11.36	38.30	11.53	40
41	39.41	11.30	39.36	11.47	39.31	11.64	39.26	11.82	41
42	40.37	11.58	40.32	11.75	40.27	11.93	40.22	12.10	42
43	41.33	11.85	41.28	12.03	41.23	12.21	41.18	12.39	43
44	42.30	12.13	42.24	12.31	42.19	12.50	12.13	12.68	44
45	43.26	12.40	43.20	12.59	43.15	12.78	43.09	12.97	45
46	44.22	12.68	44.16	12.87	44.11	13.06	44.05	13.26	46
47	45.18	12.95	45.12	13.15	45.06	13.35	45.01	13.55	47
48	46.14	13.23	46.08	13.43	46.02	13.63	45.96	13.83	48
49	47.10	13.51	47.04	13.71	46.98	13.92	46.92	14.12	49
50	48.06	13.78	48.00	13.99	47.94	14.20	47.88	14.41	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	74 Deg.		73¾ Deg.		73½ Deg.		73¼ Deg.		

Distance.	16 Deg.		16¼ Deg.		16½ Deg		16¾ Deg.		Distance
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	49.02	14.06	48.96	14.27	48.90	14.48	48.84	14.70	51
52	49.99	14.33	49.92	14.55	49 86	14.77	49.79	14.99	52
53	50.95	14.61	50.88	14 83	50.82	15.05	50.75	15.27	53
54	51.91	14.88	51.84	15 11	51.78	15.34	51.71	15.56	54
55	52.87	15.16	52.80	15.39	52.74	15.62	52.67	15 85	55
56	53.83	15.44	53.76	15.67	53.69	15.90	53.62	16 14	56
57	54.79	15.71	54.72	15.95	54.65	16.19	54.58	16.43	57
58	55.75	15.99	55.68	16.23	55.61	16.47	55.54	16.72	58
59	56.71	16.26	56.64	16.51	56.57	16.76	56.50	17.00	59
60	57.68	16.54	57.60	16.79	57.53	17.04	57.45	17.29	60
61	58.64	16.81	58.56	17.07	58.49	17.32	58.41	17.58	61
62	59.60	17.09	59.52	17.35	59.45	17.61	59.37	17.87	62
63	60.56	17.37	50 48	17.63	60.41	17.89	60.33	18.16	63
64	61.52	17.64	61.44	17.91	61.36	18.18	61.28	18.44	64
65	62.48	17.92	62.40	18.19	62.32	18.46	62.24	18.73	65
66	63.44	18.19	63.36	18.47	63.28	18.74	63.20	19.02	66
67	64.40	18.47	64.32	18.75	64.24	19.03	64.16	19.31	67
68	65.37	18.74	65.28	19.03	65.20	19.31	65.11	19.60	68
69	66.33	19.02	66.24	19.31	66.16	19.60	66.07	19.89	69
70	67.29	19.29	67.20	19.59	67.12	19.88	67.03	20.17	70
71	68.25	19.57	68.16	19.87	68.08	20.17	67.99	20.46	71
72	69.21	19.85	69.12	20.15	69.03	20.45	68.95	20.75	72
73	70.17	20.12	70.08	20.43	69.99	20.73	69.90	21.04	73
74	71.13	20.40	71.04	20.71	70.95	21 02	70.86	21.33	74
75	72.09	20.67	72.00	20.99	71.91	21.30	71.82	21.61	75
76	73.06	20.95	72.96	21.27	72.87	21.59	72.78	21.90	76
77	74.02	21.22	73.92	21.55	73.83	21.87	73.73	22.19	77
78	74.98	21.50	74.88	21.83	74.79	22.15	74.69	22.48	78
79	75.94	21.78	75.84	22.11	75.75	22.44	75.65	22.77	79
80	76.90	22.05	76.80	22.39	76.71	22.72	76.61	23.06	80
81	77.86	22.33	77.76	22.67	77.66	23.01	77.56	23.34	81
82	78.82	22.60	78.72	22.95	78.62	23.29	78.52	23.63	82
83	79.78	22.88	79.68	23.23	79.58	23.57	79.48	23.92	83
84	80.75	23.15	80.64	23.51	80.54	23.86	80.44	24.21	84
85	81.71	23.43	81.60	23.79	81.50	24.14	81.39	24.50	85
86	82.67	23.70	82.56	24.07	82.46	24.43	82.35	24.78	86
87	83.63	23.98	83.52	24.35	83.42	24.71	83.31	25.07	87
88	84.59	24.26	84.48	24.62	84.38	24.99	84.27	25.36	88
89	85.55	24.53	85.44	24.90	85.33	25.28	85.22	25.65	89
90	86.51	24.81	86.40	25.18	86.29	25.56	86.18	25.94	90
91	87.47	25.08	87.36	25.46	87.25	25.85	87.14	26.23	91
92	88.44	25.36	88.32	25.74	88.21	26.13	88.10	26.51	92
93	89.40	25.63	89.28	26.02	89.17	26.41	89.05	26.80	93
94	90.26	25.91	90.24	26.30	90.13	26.70	90.01	27.09	94
95	91.32	26.19	91.20	26.58	91.09	26.98	90.97	27.38	95
96	92.28	26.46	92.16	26.86	92.05	27.27	91.93	27.67	96
97	93.24	26.74	93.12	27.14	93.01	27.55	92.88	27.95	97
98	94.20	27.01	94.08	27.42	93.96	27.83	93.84	28.24	98
99	95.16	27.29	95.04	27.70	94.92	28.12	94.80	28.53	99
100	96.13	27.56	96.00	27.98	95.88	28.40	95.76	28.82	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	74 Deg.		73¾ Deg.		73½ Deg.		73¼ Deg.		

Distance.	17 Deg.		17¼ Deg.		17½ Deg.		17¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.96	0.29	0.95	0.30	0.95	0.30	0.95	0.30	
2	1.91	0.58	1.91	0.59	1.91	0.60	1.90	0.61	2
3	2.87	0.88	2.87	0.89	2.86	0.90	2.86	0.91	3
4	3.83	1.17	3.82	1.19	3.81	1.20	3.81	1.22	4
5	4.78	1.46	4.78	1.48	4.77	1.50	4.76	1.52	5
6	5.74	1.75	5.73	1.78	5.72	1.80	5.71	1.83	6
7	6.69	2.05	6.69	2.08	6.68	2.10	6.67	2.13	7
8	7.65	2.34	7.64	2.37	7.63	2.41	7.62	2.44	8
9	8.61	2.63	8.60	2.67	8.58	2.71	8.57	2.74	9
10	9.56	2.92	9.55	2.97	9.54	3.01	9.52	3.05	10
11	10.52	3.22	10.51	3.26	10.49	3.31	10.48	3.35	11
12	11.48	3.51	11.46	3.56	11.44	3.61	11.43	3.66	12
13	12.43	3.80	12.42	3.85	12.40	3.91	12.38	3.96	13
14	13.39	4.09	13.37	4.15	13.35	4.21	13.33	4.27	14
15	14.34	4.39	14.33	4.45	14.31	4.51	14.29	4.57	15
16	15.30	4.68	15.28	4.74	15.26	4.81	15.24	4.88	16
17	16.26	4.97	16.24	5.04	16.21	5.11	16.19	5.18	17
18	17.21	5.26	17.19	5.34	17.17	5.41	17.14	5.49	18
19	18.17	5.56	18.15	5.63	18.12	5.71	18.10	5.79	19
20	19.13	5.85	19.10	5.93	19.07	6.01	19.05	6.10	20
21	20.08	6.14	20.06	6.23	20.03	6.31	20.00	6.40	21
22	21.04	6.43	21.01	6.52	20.98	6.62	20.95	6.71	22
23	21.99	6.72	21.97	6.82	21.94	6.92	21.91	7.01	23
24	22.95	7.02	22.92	7.12	22.89	7.22	22.86	7.32	24
25	23.91	7.31	23.88	7.41	23.84	7.52	23.81	7.62	25
26	24.86	7.60	24.83	7.71	24.80	7.82	24.76	7.93	26
27	25.82	7.89	25.79	8.01	25.75	8.12	25.71	8.23	27
28	26.78	8.19	26.74	8.30	26.70	8.42	26.67	8.54	28
29	27.73	8.48	27.70	8.60	27.66	8.72	27.62	8.84	29
30	28.69	8.77	28.65	8.90	28.61	9.02	28.57	9.15	30
31	29.65	9.06	29.61	9.19	29.57	9.32	29.52	9.45	31
32	30.60	9.36	30.56	9.49	30.52	9.62	30.48	9.76	32
33	31.56	9.65	31.52	9.79	31.47	9.92	31.43	10.06	33
34	32.51	9.94	32.47	10.08	32.43	10.22	32.38	10.37	34
35	33.47	10.23	33.43	10.38	33.38	10.52	33.33	10.67	35
36	34.43	10.53	34.38	10.68	34.33	10.83	34.29	10.98	36
37	35.38	10.82	35.34	10.97	35.29	11.13	35.24	11.28	37
38	36.34	11.11	36.29	11.27	36.24	11.43	36.19	11.58	38
39	37.30	11.40	37.25	11.57	37.19	11.73	37.14	11.89	39
40	38.25	11.69	38.20	11.86	38.15	12.03	38.10	12.19	40
41	39.21	11.99	39.16	12.16	39.10	12.33	39.05	12.50	41
42	40.16	12.28	40.11	12.45	40.06	12.63	40.00	12.80	42
43	41.12	12.57	41.07	12.75	41.01	12.93	40.95	13.11	43
44	42.08	12.86	42.02	13.05	41.96	13.23	41.91	13.41	44
45	43.03	13.16	42.98	13.34	42.92	13.53	42.86	13.72	45
46	43.99	13.45	43.93	13.64	43.87	13.83	43.81	14.02	46
47	44.95	13.74	44.89	13.94	44.82	14.13	44.76	14.33	47
48	45.90	14.03	45.84	14.23	45.78	14.43	45.71	14.63	48
49	46.86	14.33	46.80	14.53	46.73	14.73	46.67	14.94	49
50	47.82	14.62	47.75	14.83	47.69	15.04	47.62	15.24	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	73 Deg.		72¾ Deg.		72½ Deg.		72¼ Deg.		

Distance.	17 Deg.		17¼ Deg.		17½ Deg.		17¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	48.77	14.91	48.71	15.12	48.64	15.34	48.57	15.55	51
52	49.73	15.20	49.66	15.42	49.59	15.64	49.52	15.85	52
53	50.68	15.50	50.62	15.72	50.55	15.94	50.48	16.16	53
54	51.64	15.79	51.57	16.01	51.50	16.24	51.43	16.46	54
55	52.60	16.08	52.53	16.31	52.45	16.54	52.38	16.77	55
56	53.55	16.37	53.48	16.61	53.41	16.84	53.33	17.07	56
57	54.51	16.67	54.44	16.90	54.36	17.14	54.29	17.38	57
58	55.47	16.96	55.39	17.20	55.32	17.44	55.24	17.68	58
59	56.42	17.25	56.35	17.50	56.27	17.74	56.10	17.99	59
60	57.38	17.54	57.30	17.79	57.22	18.04	57.14	18.29	60
61	58.33	17.83	58.26	18.09	58.18	18.34	58.10	18.60	61
62	59.29	18.13	59.21	18.39	59.13	18.64	59.05	18.90	62
63	60.25	18.42	60.17	18.68	60.08	18.94	60.00	19.21	63
64	61.20	18.71	61.12	18.98	61.04	19.25	60.95	19.51	64
65	62.16	19.00	62.08	19.28	61.99	19.55	61.91	19.82	65
66	63.12	19.30	63.03	19.57	62.95	19.35	62.86	20.12	66
67	64.07	19.59	63.99	19.87	63.90	20.15	63.81	20.43	67
68	65.03	19.88	64.94	20.16	64.85	20.45	64.76	20.73	68
69	65.99	20.17	65.90	20.46	65.81	20.75	65.72	21.04	69
70	66.94	20.47	66.85	20.76	66.76	21.05	66.67	21.34	70
71	67.90	20.76	67.81	21.05	67.71	21.35	67.62	21.65	71
72	68.85	21.05	68.76	21.35	68.67	21.65	68.57	21.95	72
73	69.81	21.34	69.72	21.65	69.62	21.95	69.52	22.26	73
74	70.77	21.64	70.67	21.94	70.58	22.25	70.48	22.56	74
75	71.72	21.93	71.63	22.24	71.53	22.55	71.43	22.86	75
76	72.68	22.22	72.58	22.54	72.48	22.85	72.38	23.17	76
77	73.64	22.51	73.54	22.83	73.44	23.15	73.33	23.47	77
78	74.59	22.80	74.49	23.13	74.39	23.46	74.29	23.78	78
79	75.55	23.10	75.45	23.43	75.34	23.76	75.24	24.08	79
80	76.50	23.39	76.40	23.72	76.30	24.06	76.19	24.39	80
81	77.46	23.68	77.36	24.02	77.25	24.36	77.14	24.69	81
82	78.42	23.97	78.31	24.32	78.20	24.66	78.10	25.00	82
83	79.37	24.27	79.27	24.61	79.16	25.96	79.05	25.30	83
84	80.33	24.56	80.22	24.91	80.11	25.26	80.00	25.61	84
85	81.29	24.85	81.18	25.21	81.07	25.56	80.95	25.91	85
86	82.24	25.14	82.13	25.50	82.02	25.86	81.91	26.22	86
87	83.20	25.44	83.09	25.80	82.97	26.16	82.86	26.52	87
88	84.15	25.73	84.04	26.10	83.93	26.46	83.81	26.83	88
89	85.11	26.02	85.00	26.39	84.88	26.76	84.76	27.13	89
90	86.07	26.31	85.95	26.69	85.83	27.06	85.72	27.44	90
91	87.02	26.61	86.91	26.99	86.79	27.36	86.67	27.74	91
92	87 98	26.90	87.86	27.28	87.74	27.66	87.62	28.05	92
93	88.94	27.19	88.82	27.58	88.70	27.97	88.57	28.35	93
94	89.89	27.48	89.77	27.87	89.65	28.27	89.53	28.66	94
95	90.85	27.78	90.73	28.17	90.60	28.57	90.48	28.96	95
96	91 81	28.07	91.68	28.47	91.56	28.87	91.43	29.27	96
97	92.76	28.36	92.64	28.76	92.51	29.17	92.38	29.57	97
98	93.72	28.65	93.59	29.06	93.46	29.47	93.33	29.88	98
99	94.67	28.94	94.55	29.36	94.42	29.77	94.29	30.18	99
100	95.63	29.24	95.50	29.65	95.37	30 07	95.24	30.49	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	73 Deg.		72¾ Deg.		72½ Deg.		72¼ Deg.		

Distance.	18 Deg.		18¼ Deg.		18½ Deg.		18¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.95	0.31	0.95	0.31	0.95	0.32	0.95	0.32	1
2	1.90	0.62	1.90	0.63	1.90	0.63	1.89	0.64	2
3	2.85	0.93	2.85	0.94	2.84	0.95	2.84	0.96	3
4	3.80	1.24	3.80	1.25	3.79	1.27	3.79	1.29	4
5	4.76	1.55	4.75	1.57	4.74	1.59	4.73	1.61	5
6	5.71	1.85	5.70	1.88	5.69	1.90	5.68	1.93	6
7	6.66	2.16	6.65	2.19	6.64	2.22	6.63	2.25	7
8	7.61	2.47	7.60	2.51	7.59	2.54	7.58	2.57	8
9	8.56	2.78	8.55	2.82	8.53	2.86	8.52	2.89	9
10	9.51	3.09	9.50	3.12	9.48	3.17	9.47	3.21	10
11	10.46	3.40	10.45	3.44	10.43	3.49	10.42	3.54	11
12	11.41	3.71	11.40	3.76	11.38	3.81	11.36	3.86	12
13	12.36	4.02	12.35	4.07	12.33	4.12	12.31	4.18	13
14	13.31	4.33	13.30	4.38	13.28	4.44	13.26	4.50	14
15	14.27	4.64	14.25	4.70	14.22	4.76	14.20	4.82	15
16	15.22	4.94	15.20	5.01	15.17	5.08	15.15	5.14	16
17	16.17	5.25	16.14	5.32	16.12	5.39	16.10	5.46	17
18	17.12	5.56	17.09	5.64	17.07	5.71	17.04	5.79	18
19	18.07	5.87	18.04	5.95	18.02	6.03	17.99	6.11	19
20	19.02	6.18	18.99	6.26	18.97	6.35	18.94	6.43	20
21	19.97	6.49	19.94	6.58	19.91	6.66	19.89	6.75	21
22	20.92	6.80	20.89	6.89	20.86	6.98	20.83	7.07	22
23	21.87	7.11	21.84	7.20	21.81	7.30	21.78	7.39	23
24	22.83	7.42	22.79	7.52	22.76	7.62	22.73	7.71	24
25	23.78	7.73	23.74	7.83	23.71	7.93	23.67	8.04	25
26	24.73	8.03	24.69	8.14	24.66	8.25	24.62	8.36	26
27	25.68	8.34	25.64	8.46	25.60	8.57	25.57	8.68	27
28	26.63	8.65	26.59	8.77	26.55	8.88	26.51	9.00	28
29	27.58	8.96	27.54	9.08	27.50	9.20	27.46	9.32	29
30	28.53	9.27	28.49	9.39	28.45	9.52	28.41	9.64	30
31	29.48	9.58	29.44	9.71	29.40	9.84	29.35	9.96	31
32	30.43	9.89	30.39	10.02	30.35	10.15	30.30	10.29	32
33	31.38	10.20	31.34	10.33	31.29	10.47	31.25	10.61	33
34	32.34	10.51	32.29	10.65	32.24	10.79	32.20	10.93	34
35	33.29	10.82	33.24	10.96	33.19	11.11	33.14	11.25	35
36	34.24	11.12	34.19	11.27	34.14	11.42	34.09	11.57	36
37	35.19	11.43	35.14	11.59	35.09	11.74	35.04	11.89	37
38	36.14	11.74	36.09	11.90	36.04	12.06	35.98	12.21	38
39	37.09	12.05	37.04	12.21	36.98	12.37	36.93	12.54	39
40	38.04	12.36	37.99	12.53	37.93	12.69	37.88	12.86	40
41	38.99	12.67	38.94	12.84	38.88	13.01	38.82	13.18	41
42	39.94	12.98	39.89	13.15	39.83	13.33	39.77	13.50	42
43	40.90	13.29	40.84	13.47	40.78	13.64	40.72	13.82	43
44	41.85	13.60	41.79	13.78	41.73	13.96	41.66	14.14	44
45	42.80	13.91	42.74	14.09	42.67	14.28	42.61	14.46	45
46	43.75	14.21	43.69	14.41	43.62	14.60	43.56	14.79	46
47	44.70	14.52	44.64	14.72	44.57	14.91	44.51	15.11	47
48	45.65	14.83	45.59	15.03	45.52	15.23	45.45	15.43	48
49	46.60	15.14	46.54	15.35	46.47	15.55	46.40	15.75	49
50	47.55	15.45	47.48	15.66	47.42	15.87	47.35	16.07	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	72 Deg.		71¾ Deg.		71½ Deg.		71¼ Deg.		

Distance.	18 Deg.		18¼ Deg.		18½ Deg.		18¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	48.50	15.76	48.43	15.97	48.36	16.18	48.29	16.39	51
52	49.45	16.07	49.38	16.28	49.31	16.50	49.24	16 71	52
53	50.41	16.38	50.33	16.60	50.26	16.82	50.19	17.04	53
54	51.36	16.69	51.28	16.91	51.21	17.13	51.13	17.36	54
55	52.31	17.00	52.23	17.22	52.16	17.45	52.08	17.68	55
56	53.26	17.30	53.18	17.54	53.11	17.77	53.03	18.00	56
57	54.21	17.61	54.13	17.85	54.05	18.09	53.98	18.32	57
58	55.16	17.92	55.08	18.16	55.00	18.40	54.92	18.64	58
59	56.11	18.23	56.03	18.48	55.95	18.72	55.87	18.96	59
60	57.06	18.54	56.98	18.79	56.90	19.04	56.82	19.29	60
61	58.01	18 85	57.93	19.10	57.85	19.36	57.76	19.61	61
62	58.97	19.16	58.88	19.42	58.80	19.67	58.71	19.93	62
63	59.92	19.47	59.83	19.73	59.74	19.99	59.66	20.25	63
64	60.87	19.78	60.78	20.04	60.69	20.31	60.60	20.57	64
65	61.82	20.09	61.73	20.36	61.64	20.62	61.55	20.89	65
66	62.77	20.40	62.68	20.67	62.59	20.94	62.50	21.22	66
67	63.72	20.70	63.63	20.98	63.54	21.26	63.44	21.54	67
68	64.67	21.01	64.58	21.30	64.49	21.58	64.39	21.86	68
69	65.62	21.32	65.53	21.61	65.43	21.89	65.34	22.18	69
70	66.57	21.63	66.48	21.92	66.38	22.21	66.29	22.50	70
71	67.53	21.94	67.43	22.23	67.33	22.53	67.23	22.82	71
72	68.48	22.25	68.38	22.55	68.28	22.85	68.18	23.14	72
73	69.43	22.56	69.33	22.86	69.23	23.16	69.13	23.47	73
74	70.38	22.87	70.28	23.17	70.18	23.48	70.07	23.79	74
75	71.33	23.18	71.23	23.49	71.12	23.80	71.02	24.11	75
76	72.28	23.49	72.18	23.80	72.07	24.12	71.97	24.43	76
77	73 23	23.79	73.13	24.11	73.02	24.43	72.91	24.75	77
78	74.18	24.10	74.08	24.43	73.97	24.75	73.86	25.07	78
79	75.13	24.41	75.03	24.74	74.92	25.07	74.81	25.39	79
80	76.08	24.72	75.98	25.05	75.87	25.38	75.75	25.72	80
81	77.04	25.03	76.93	25.37	76.81	25.70	76.70	26.04	81
82	77.99	25.34	77.88	25.68	77.76	26.02	77.65	26.36	82
83	78.94	25.65	78.83	25.99	78.71	26.34	78.60	26.68	83
84	79.89	25.96	79.77	26.31	79.66	26.65	79.54	27.00	84
85	80.84	26.27	80.72	26.62	80.61	26.97	80.49	27.32	85
86	81.79	26.58	81.67	26.93	81.56	27.29	81.44	27.64	86
87	82.74	26.88	82.62	27.25	82.50	27.61	82.38	27.97	87
88	83.69	27.19	83.57	27.56	83.45	27.92	83.33	28.29	88
89	84.64	27.50	84.52	27.87	84.40	28.24	84.28	28.61	89
90	85.60	27.81	85.47	28.18	85.35	28.56	85.22	28.93	90
91	86.55	28.12	86.42	28.50	86.30	28.87	86.17	29.25	91
92	87.50	28.43	87.37	28.81	87.25	29.19	87.12	29.57	92
93	88.45	28.74	88.32	29.12	88.19	29.51	88.06	29.89	93
94	89.40	29.05	89.27	29.44	89.14	29.83	89.01	30.22	94
95	90.35	29.36	90.22	29.75	90.09	30.14	89.96	30.54	95
96	91.30	29.67	91.17	30.06	91.04	30.46	90.91	30.86	96
97	92.25	29.97	92.12	30.38	91.99	30.78	91.85	31.18	97
98	93.20	30.28	93.07	30.69	92.94	31.10	92.80	31.50	98
99	94.15	30.59	94.02	31.00	93.88	31.41	93.75	31.82	99
100	95.11	30.90	94.97	31.32	94.83	31.73	94.69	32 14	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	72 Deg.		71¾ Deg.		71½ Deg.		71¼ Deg.		

Distance.	19 Deg.		19¼ Deg.		19½ Deg.		19¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.95	0.33	0.94	0.33	0.94	0.33	0.94	0.34	1
2	1.89	0.65	1.89	0.66	1.89	0.67	1.88	0.68	2
3	2.84	0.98	2.83	0.99	2.83	1.00	2.82	1.01	3
4	3.78	1.30	3.78	1.32	3.77	1.34	3.76	1.35	4
5	4.73	1.63	4.72	1.65	4.71	1.67	4.71	1.69	5
6	5.67	1.95	5.66	1.98	5.66	2.00	5.65	2.03	6
7	6.62	2.28	6.61	2.31	6.60	2.34	6.59	2.37	7
8	7.56	2.60	7.55	2.64	7.54	2.67	7.53	2.70	8
9	8.51	2.93	8.50	2.97	8.48	3.00	8.47	3.04	9
10	9.46	3.26	9.44	3.30	9.43	3.34	9.41	3.38	10
11	10.40	3.58	10.38	3.63	10.37	3.67	10.35	3.72	11
12	11.35	3.91	11.33	3.96	11.31	4.01	11.29	4.06	12
13	12.29	4.23	12.27	4.29	12.25	4.34	12.24	4.39	13
14	13.24	4.56	13.22	4.62	13.20	4.67	12.18	4.73	14
15	14.18	4.88	14.16	4.95	14.14	5.01	14.12	5.07	15
16	15.13	5.21	15.11	5.28	15.08	5.34	15.06	5.41	16
17	16.07	5.53	16.05	5.60	16.02	5.67	16.00	5.74	17
18	17.02	5.86	16.99	5.93	16.97	6.01	16.94	6.08	18
19	17.96	6.19	17.94	6.26	17.91	6.34	17.88	6.42	19
20	18.91	6.51	18.88	6.59	18.85	6.68	18.82	6.76	20
21	19.86	6.84	19.83	6.92	19.80	7.01	19.76	7.10	21
22	20.80	7.16	20.77	7.25	20.74	7.34	20.71	7.43	22
23	21.75	7.49	21.71	7.58	21.68	7.68	21.65	7.77	23
24	22.69	7.81	22.66	7.91	22.62	8.01	22.59	8.11	24
25	23.64	8.14	23.60	8.24	23.57	8.35	23.53	8.45	25
26	24.58	8.46	24.55	8.57	24.51	8.68	24.47	8.79	26
27	25.53	8.79	25.49	8.90	25.45	9.01	25.41	9.12	27
28	26.47	9.12	26.43	9.23	26.39	9.35	26.35	9.46	28
29	27.42	9.44	27.38	9.56	27.34	9.68	27.29	9.80	29
30	28.37	9.77	28.32	9.89	28.28	10.01	28.24	10.14	30
31	29.31	10.09	29.27	10.22	29.22	10.35	29.18	10.48	31
32	30.26	10.42	30.21	10.55	30.16	10.68	30.12	10.81	32
33	31.20	10.74	31.15	10.88	31.11	11.02	31.06	11.15	33
34	32.15	11.07	32.10	11.21	32.05	11.35	32.00	11.49	34
35	33.09	11.39	33.04	11.54	32.99	11.68	32.94	11.83	35
36	34.04	11.72	33.99	11.87	33.94	12.02	33.88	12.17	36
37	34.98	12.05	34.93	12.20	34.88	12.35	34.82	12.50	37
38	35.93	12.37	35.88	12.53	35.82	12.68	35.76	12.84	38
39	36.88	12.70	36.82	12.86	36.76	13.02	36.71	13.18	39
40	37.82	13.02	37.76	13.19	37.71	13.35	37.65	13.52	40
41	38.77	13.35	38.71	13.52	38.65	13.69	38.59	13.85	41
42	39.71	13.67	39.65	13.85	39.59	14.02	29.53	14.19	42
43	40.66	14.00	40.60	14.18	40.53	14.35	40.47	14.53	43
44	41.60	14.32	41.54	14.51	41.48	14.69	41.41	14.87	44
45	42.55	14.65	42.48	14.84	42.42	15.02	42.35	15.21	45
46	43.49	14.98	43.43	15.17	43.36	15.36	43.29	15.54	46
47	44.14	15.30	44.37	15.50	44.30	15.69	44.24	15.88	47
48	45.38	15.63	45.32	15.83	45.25	16.02	45.18	16.22	48
49	46.33	15.95	46.26	16.15	46.19	16.36	46.12	16.56	49
50	47.28	16.28	47.20	16.48	47.13	16.59	47.06	16.90	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	71 Deg.		70¾ Deg.		70½ Deg.		70¼ Deg.		

Distance.	19 Deg.		19¼ Deg.		19½ Deg.		19¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	48 22	16.60	48.15	16.81	48.07	17.02	48.00	17.23	51
52	49.17	16.93	49.09	17.14	49.02	17.36	48.94	17.57	52
53	50.11	17.26	50.04	17.47	49.96	17.69	49.88	17.91	53
54	51.06	17.58	50.98	17.80	50.90	18.03	50.82	18.25	54
55	52.00	17.91	51.92	18.13	51.85	18.36	51.76	18.59	55
56	52.95	18 23	52.87	18.46	52.79	18.69	52.71	18.92	56
57	53.89	18.56	53.81	18.79	53.73	19.03	53.65	19.26	57
58	54.84	18.88	54.76	19.12	54.67	19.36	54.59	19.60	58
59	55.79	19.21	55.70	19.45	55.62	19.69	55.53	19.94	59
60	56.73	19.53	56.65	19.78	56.56	20.03	56.47	20.27	60
61	57.68	19.86	57.59	20.11	57.50	20.36	57.41	20.61	61
62	58.62	20.19	58.53	20.44	58.44	20.70	58.35	20.95	62
63	59.57	20.51	59.48	20.77	59.39	21.03	59.29	21.29	63
64	60.51	20.84	60.42	21.10	60.33	21.36	60.24	21.63	64
65	61.46	21.16	61.37	21.43	61.27	21.70	61.18	21.96	65
66	62.40	21.49	62.31	21.76	62.21	22.03	62.12	22.30	66
67	63.35	21.81	63.25	22.09	63.16	22.37	63.06	22.64	67
68	64.30	22.14	64.20	22.42	64.10	22.70	64.00	22.98	68
69	65.24	22.46	65.14	22.75	65.04	23.03	64.94	23.32	69
70	66.19	22.79	66.09	23.08	65.98	23.37	65.88	23.65	70
71	67.13	23.12	67.03	23.41	66.93	23.70	66.82	23.99	71
72	68.08	23.44	67.97	23.74	67.87	24.03	67.76	24.33	72
73	69.02	23.77	68.92	24.07	68.81	24.37	68.71	24.67	73
74	69.97	24.09	69.86	24.40	69.76	24.70	69.65	25.01	74
75	70.91	24.42	70.81	24.73	70.70	25.04	70.59	25.34	75
76	71.86	24.74	71.75	25.06	71.64	25.37	71.53	25.68	76
77	72.80	25.07	72.69	25.39	72.58	25.70	72.47	26.02	77
78	73.75	25.39	73.64	25.72	73.53	26.04	73.41	26.36	78
79	74.70	25.72	74.58	26.05	74.47	26.37	74.35	26.70	79
80	75.64	26.05	75.53	26.38	75.41	26.70	75.29	27.03	80
81	76.59	26.37	76.47	26.70	76.35	27.04	76.24	27.37	81
82	77.53	26.70	77.42	27.03	77.30	27.37	77.18	27.71	82
83	78.48	27.02	78.36	27.36	78.24	27.71	78.12	28.05	83
84	79.42	27.35	79.30	27.69	79.18	28.04	79.06	28.39	84
85	80.37	27.67	80.25	28.02	80.12	28.37	80.00	28.72	85
86	81.31	28.00	81.19	28.35	81.07	28.71	80.94	29.06	86
87	82.26	28.32	82.14	28.68	82.01	29.04	81.88	29.40	87
88	83.21	28.65	83.08	29.01	92.95	29.37	82.82	29.74	88
89	84.15	28.98	84.02	29.34	83.90	29.71	83.76	30.07	89
90	85.10	29.30	84.97	29.67	84.84	30.04	84.71	30.41	90
91	86.04	29.63	85.91	30.00	85.78	30.38	85.65	30.75	91
92	86.99	29.95	86.86	30.33	86.72	30.71	86.59	31.09	92
93	87.93	30.28	87.80	30.66	87.67	31.04	87.53	31.43	93
94	88.88	30.60	88.74	30.99	88.61	31.38	88.47	31.76	94
95	89.82	30.93	89.69	31.32	89.55	31.71	89.41	32.10	95
96	90.77	31.25	90.63	31.65	90.49	32.05	90.35	32.44	96
97	91.72	31.58	91.58	31.98	91.44	32.38	91.29	32.78	97
98	92.66	31.91	92.52	32.31	92.38	32.71	92.24	33.12	98
99	93.61	32.23	93.46	32.64	93.32	33.05	93.18	33.45	99
100	94.55	32.56	94.41	32.97	94.26	33.38	94.12	33.79	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	71 Deg.		70¾ Deg.		70½ Deg.		70¼ Deg.		

Distance.	20 Deg.		20¼ Deg.		20½ Deg.		20¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.94	0.34	0.94	0.35	0.94	0.35	0.94	0.36	
2	1.88	0.68	1.88	0.69	1.87	0.70	1.87	0.71	2
3	2.82	1.03	2.81	1.04	2.81	1.05	2.81	1.06	3
4	3.76	1.37	3.75	1.38	3.75	1.40	3.74	1.42	4
5	4.70	1.71	4.69	1.73	4.68	1.75	4.68	1.77	5
6	5.64	2.05	5.63	2.08	5.62	2.10	5.61	2.13	6
7	6.58	2.39	6.57	2.42	6.56	2.45	6.55	2.48	7
8	7.52	2.74	7.51	2.77	7.49	2.80	7.48	2.83	8
9	8.46	3.08	8.44	3.12	8.43	3.15	8.42	3.19	9
10	9.40	3.42	9.38	3.46	9.37	3.50	9.35	3.54	10
11	10.34	3.76	10.32	3.81	10.30	3.85	10.29	3.90	11
12	11.28	4.10	11.26	4.15	11.24	4.20	11.22	4.25	12
13	12.22	4.45	12.20	4.50	12.18	4.55	12.16	4.61	13
14	13.16	4.79	13.13	4.85	13.11	4.90	13.09	4.96	14
15	14.10	5.13	14.07	5.19	14.05	5.25	14.03	5.31	15
16	15.04	5.47	15.01	5.54	14.99	5.60	14.96	5.67	16
17	15.97	5.81	15.95	5.88	15.92	5.95	15.90	6.02	17
18	16.91	6.16	16.89	6.23	16.86	6.30	16.83	6.38	18
19	17.85	6.50	17.83	6.58	17.80	6.65	17.77	6.73	19
20	18.79	6.84	18.76	6.92	18.73	7.00	18.70	7.09	20
21	19.73	7.18	19.70	7.27	19.67	7.35	19.64	7.44	21
22	20.67	7.52	20.64	7.61	20.61	7.70	20.57	7.79	22
23	21.61	7.87	21.58	7.96	21.54	8.05	21.51	8.15	23
24	22.55	8.21	22.52	8.31	22.48	8.40	22.44	8.50	24
25	23.49	8.55	23.45	8.65	23.42	8.76	23.38	8.86	25
26	24.43	8.89	24.39	9.00	24.35	9.11	24.31	9.21	26
27	25.37	9.23	25.33	9.35	25.29	9.46	25.25	9.57	27
28	26.31	9.58	26.27	9.69	26.23	9.81	26.18	9.92	28
29	27.25	9.92	27.21	10.04	27.16	10.16	27.12	10.27	29
30	28.19	10.26	28.15	10.38	28.10	10.51	28.05	10.63	30
31	29.13	10.60	29.08	10.73	29.04	10.86	28.99	10.98	31
32	30.07	10.94	30.02	11.08	29.97	11.21	29.92	11.34	32
33	31.01	11.29	30.96	11.42	30.91	11.56	30.86	11.69	33
34	31.95	11.63	31.90	11.77	31.85	11.91	31.79	12.05	34
35	32.89	11.97	32.84	12.11	32.78	12.26	32.73	12.40	35
36	33.83	12.31	33.77	12.46	33.72	12.61	33.66	12.75	36
37	34.77	12.65	34.71	12.81	34.66	12.96	34.60	13.11	37
38	35.71	13.00	35.65	13.15	35.59	13.31	35.54	13.46	38
39	36.65	13.34	36.59	13.50	36.53	13.66	36.47	13.82	39
40	37.59	13.68	37.53	13.84	37.47	14.01	37.41	14.17	40
41	38.53	14.02	38.47	14.19	38.40	14.36	38.34	14.53	41
42	39.47	14.36	39.40	14.54	39.34	14.71	39.28	14.88	42
43	40.41	14.71	40.34	14.88	40.28	15.06	40.21	15.23	43
44	41.35	15.05	41.28	15.23	41.21	15.41	41.15	15.59	44
45	42.29	15.39	42.22	15.58	42.15	15.76	42.08	15.94	45
46	43.23	15.73	43.16	15.92	43.09	16.11	43.02	16.30	46
47	44.17	16.07	44.09	16.27	44.02	16.46	43.95	16.65	47
48	45.11	16.42	45.03	16.61	44.96	16.81	44.89	17.01	48
49	46.04	16.76	45.97	16.96	45.90	17.16	45.82	17.36	49
50	46.98	17.10	46.91	17.31	46.83	17.51	46.76	17.71	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	70 Deg.		69¾ Deg.		69½ Deg.		69¼ Deg.		

Distance.	20 Deg.		20¼ Deg.		20½ Deg		20¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	47.92	17.44	47.35	17.65	47.77	17.86	47.69	18.07	51
52	48.86	17.79	48.79	18.00	48.71	18.21	48.63	18.42	52
53	49.80	18.13	49.72	18.34	49.64	18.56	49.56	18.78	53
54	50.74	18.47	50.66	18.69	50.58	18.91	50.50	19.13	54
55	51.68	18.81	51.60	19.04	51.52	19.26	51.43	19.49	55
56	52.62	19.15	52.54	19.38	52.45	19.61	52.37	19.84	56
57	53.56	19.50	53.48	19.73	53.39	19.96	53.30	20.19	57
58	54.50	19.84	54.42	20.07	54.33	20.31	54.24	20.55	58
59	55.44	20.18	55.35	20.42	55.26	20.66	55.17	20.90	59
60	56.38	20.52	56.29	20.77	56.20	21.01	56.11	21.26	60
61	57.32	20.86	57.23	21.11	57.14	21.36	57.04	21.61	61
62	58.26	21.21	58.17	21.46	58.07	21.71	57.98	21.97	62
63	59.20	21.55	59.11	21.81	59.01	22.06	58.91	22.32	63
64	60.14	21.89	60.04	22.15	59.95	22.41	59.85	22.67	64
65	61.08	22.23	60.98	22.50	60.88	22.76	60.78	23.03	65
66	62.02	22.57	61.92	22.84	61.82	23.11	61.72	23.38	66
67	62.96	22.92	62.86	23.19	62.76	23.46	62.65	23.74	67
68	63.90	23.26	63.80	23.54	63.69	23.81	63.59	24.09	68
69	64.84	23.60	64.74	23.88	64.63	24.16	64.52	24.45	69
70	65.78	23.94	65.67	24.23	65.57	24.51	65.46	24.80	70
71	66.72	24.28	66.61	24.57	66.50	24.86	66.39	25.15	71
72	67.66	24.63	67.55	24.92	67.44	25.21	67.33	25.51	72
73	68.60	24.97	68.49	25.27	68.38	25.57	68.26	25.86	73
74	69.54	25.31	69.43	25.61	69.31	25.92	69.20	26.22	74
75	70.48	25.65	70.36	25.96	70.25	26.27	70.14	26.57	75
76	71.42	25.99	71.30	26.30	71.19	26.62	71.07	26.93	76
77	72.36	26.34	72.24	26.65	72.12	26.97	72.01	27.28	77
78	73.30	26.68	73.18	27.00	73.06	27.32	72.94	27.63	78
79	74.24	27.02	74.12	27.34	74.00	27.67	73.88	27.99	79
80	75.18	27.36	75.06	27.69	74.93	28.02	74.81	28.34	80
81	76.12	27.70	75.99	28.04	75.87	28.37	75.75	28.70	81
82	77.05	28.05	76.93	28.38	76.81	28.72	76.68	29.05	82
83	77.99	28.39	77.87	28.73	77.74	29.07	77.62	29.41	83
84	78.93	28.73	78.81	29.07	78.68	29.42	78.55	29.76	84
85	79.87	29.07	79.75	29.42	79.62	29.77	79.49	30.11	85
86	80.81	29.41	80.68	29.77	80.55	30.12	80.42	30.47	86
87	81.75	29.76	81.62	30.11	81.49	30.47	81.36	30.82	87
88	82.69	30.10	82.56	30.46	82.43	30.82	82.29	31.18	88
89	83.63	30.44	83.50	30.80	83.36	31.17	83.23	31.53	89
90	84.57	30.78	84.44	31.15	84.30	31.52	84.16	31.89	90
91	85.51	31.12	85.38	31.50	85.24	31.87	85.10	32.24	91
92	86.45	31.47	86.31	31.84	86.17	32.22	86.03	32.59	92
93	87.39	31.81	87.25	32.19	87.1.	32.57	86.97	32.95	93
94	88.33	32.15	88.19	32.54	88.05	32.92	87.90	33.30	94
95	89.27	32.49	89.13	32.88	88.98	33.27	88.84	33.66	95
96	90.21	32.83	90.07	33.23	89.92	33.62	89.77	34.01	96
97	91.15	33.18	91.00	33.57	90.86	33.97	90.71	34.37	97
98	92.09	33.52	91.94	33.92	91.79	34.32	91.64	34.72	98
99	93.03	33.86	92.88	34.27	92.73	34.67	92.58	35.07	99
100	93.97	34.20	93.82	34.61	93.67	35.02	93.51	35.43	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
	70 Deg.		69¾ Deg.		69½ Deg		69¼		

Distance.	21 Deg.		21¼ Deg.		21½ Deg.		21¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.93	0.36	0.93	0.36	0.93	0.37	0.93	0.37	1
2	1.87	0.72	1.86	0.72	1.86	0.73	1.86	0.74	2
3	2.80	1.98	2.80	1.09	2.79	1.10	2.79	1.11	3
4	3.73	1.43	3.73	1.45	3.72	1.47	3.72	1.48	4
5	4.67	1.79	4.66	1.81	4.65	1.83	4.64	1.85	5
6	5.60	2.15	5.59	2.17	5.58	2.20	5.57	2.22	6
7	6.54	2.51	6.52	2.54	6.51	2.57	6.50	2.59	7
8	7.47	2.87	7.46	2.90	7.44	2.93	7.43	2.96	8
9	8.40	3.23	8.39	3.26	8.37	3.30	8.36	3.34	9
10	9.34	3.58	9.32	3.62	9.30	3.67	9.29	3.71	10
11	10.27	3.94	10.25	3.99	10.23	4.03	10.22	4.08	11
12	11,20	4.30	11.18	4.35	11.17	4.40	11.15	4.45	12
13	12.14	4.66	12.12	4.71	12.10	4.76	12.07	4.82	13
14	13.07	5.02	13.05	5.07	13.03	5.13	13.00	5.19	14
15	14.00	5.38	13.98	5.44	13.96	5.50	13.93	5.56	15
16	14.94	5.73	14.91	5.80	14.89	5.86	14.86	5.93	16
17	15.87	6.09	15.84	6.16	15.82	6.23	15.79	6.30	17
18	16.80	6.45	16.78	6.52	16.75	6.60	16.72	6.67	18
19	17.74	6.81	17.71	6.89	17.68	6.96	17.65	7.04	19
20	18.67	7.17	18.64	7.25	18.61	7.33	18.58	7.41	20
21	19.61	7.53	19.57	7.61	19.54	7.70	19.50	7.78	21
22	20.54	7.88	20.50	7.97	20.47	8.06	20.43	8.15	22
23	21.47	8.24	21.44	8.34	21.40	8.43	21.36	8.52	23
24	22.41	8.60	22.37	8.70	22.33	8.80	22.29	8.89	24
25	23.34	8.96	23.30	9.06	23.26	9.16	23.22	9.26	25
26	24.27	9.32	24.23	9.42	24.19	9.53	24.15	9.63	26
27	25.21	9.68	25.16	9.79	25.12	9.90	25.08	10.01	27
28	26.14	10.03	26.10	10.15	26.05	10.26	26.01	10 38	28
29	27.07	10.39	27.03	10.51	26.98	10.63	26.94	10.75	29
30	28.01	10.75	27.96	10.87	27.91	11.00	27.86	11.12	30
31	28.94	11.11	28.89	11.24	28.84	11.36	28.79	11.49	31
32	29.87	11.47	29.82	11.60	29.77	11.73	29.72	11.86	32
33	30.81	11.83	30.76	11.96	30.70	12.09	30.65	12.23	33
34	31.74	12.18	31.69	12.32	31.63	12.46	31.58	12.60	34
35	32.68	12.54	32.62	12.69	32.56	12.83	32.51	12.97	35
36	33.61	12.90	33.55	13.05	33.50	13.19	33.44	13.34	36
37	34.54	13.26	34.48	13.41	34.43	13.56	34.37	13.71	37
38	35.48	13.62	35.42	13.77	35.36	13.93	35.29	14.08	38
39	36.41	13.98	36.35	14.14	36.29	14.29	36.22	14.45	39
40	37.34	14.33	37.28	14.50	37.22	14.66	37.15	14.82	40
41	38.28	14.69	38.21	14.86	38.15	15.03	38.08	15.19	41
42	39.21	15.05	39.14	15.22	39.08	15.39	39.01	15.56	42
43	40.14	15.41	40.08	15.58	40.01	15.76	39.94	15.93	43
44	41.08	15.77	41.01	15.95	40.94	16.13	40.87	16.30	44
45	42.01	16.13	41.94	16.31	41.87	16.49	41.80	16.68	45
46	42.94	16.48	42.87	16.67	42.80	16.86	42.73	17.05	46
47	43.88	16.84	43.80	17.03	43.73	17.23	43.65	17.42	47
48	44.81	17.20	44.74	17.40	44.66	17.59	44.58	17.79	48
49	45.75	17.56	45.67	17.76	45.59	17.96	45.51	18.16	49
50	46.68	17.92	46.60	18.12	46.52	18.33	46.44	18.53	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	69 Deg.		68¾ Deg		68½ Deg.		68¼ Deg.		

Distance.	21 Deg.		21¼ Deg.		21½ Deg.		21¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	47.61	18.28	47.53	18.48	47.45	18.69	47.37	18 90	51
52	48.55	18.64	48.46	18 85	48.38	19.06	48.30	19.27	52
53	49.48	18.99	49.40	19.21	49.31	19.42	49.23	19.64	53
54	50.41	19.35	50.33	19.57	50.24	19.79	50.16	20.01	54
55	51 35	19.71	51.26	19.93	51.17	20.16	51.08	20.38	55
56	52 28	20.07	52.19	20.30	52.10	20.52	52.01	20.75	56
57	53 21	20.43	53.12	20.66	53.03	20.89	52.94	21.12	57
58	54.15	20.79	54.06	21.02	53.96	21.26	53.87	21.49	58
59	55.08	21.14	54.99	21.38	54.89	21.62	54.80	21.86	59
60	56.01	21.50	55.92	21.75	55.83	21.99	55.73	22.22	60
61	56.95	21.86	56.85	22.11	56.76	22.36	56.66	22.60	61
62	57 88	22.22	57.78	22.47	57.69	22.72	57.59	22.97	62
63	58.82	22.58	58.72	22.83	58.62	23.09	58.52	23.35	63
64	59.75	22.94	59.65	23.20	59.55	23.46	59.44	23.72	64
65	60.68	23.29	60.58	23.56	60.48	23.82	60.37	24.09	65
66	61.62	23.65	61.51	23.92	61.41	24.19	61.30	24.46	66
67	62.55	24.01	62.44	24.28	62.34	24.56	62.23	24.83	67
68	63.48	24.37	63.38	24.65	63.27	24.92	63.16	25.20	68
69	64.42	24.73	64.31	25.01	64.20	25.29	64.09	25.57	69
70	65.35	25.09	65.24	25.37	65.13	25.66	65.02	25.94	70
71	66.28	25.44	66.17	25.73	66.06	26.02	65.95	26.31	71
72	67.22	25.80	67.10	26.10	66.99	26.39	66.87	26.68	72
73	68.15	26.16	68.04	26.46	67.92	26.75	67.80	27.05	73
74	69.08	26.52	68.97	26.82	68.85	27.12	68.73	27.42	74
75	70.02	26.88	69.90	27.18	69.78	27.49	69.66	27.79	75
76	70.95	27.24	70.83	27.55	70.71	27.85	70.59	28.16	76
77	71.89	27.59	71.76	27.91	71.64	28.22	71.52	28.53	77
78	72.82	27.95	72.70	28.27	72.57	28.59	72.45	28.90	78
79	73.75	28.31	73.63	28.63	73.50	28.95	73.38	29.27	79
80	74.69	28.67	74.56	29.00	74.43	29.32	74.30	29.64	80
81	75.62	29.03	75.49	29.36	75.36	29.69	75.23	30.02	81
82	76.55	29.39	76.42	29.72	76.29	30.05	76.16	30.39	82
83	77.49	29.74	77.36	30.08	77.22	30.42	77.09	30.76	83
84	78.42	30.10	78.29	30.44	78.16	30.79	78.02	31.13	84
85	79.35	30.46	79.22	30.81	79.09	31.15	78.95	31.50	85
86	80.29	30.82	80.15	31.17	80.02	31.52	79.88	31.87	86
87	81.22	31.18	81.08	31.53	80.95	31.89	80.81	32.24	87
88	82.16	31 54	82.02	31.89	81.88	32.25	81.74	32.61	88
89	83.09	31.89	82.95	32.26	82.81	32.62	82.66	32.98	89
90	84.02	32.25	83.88	32.62	83.74	32.99	83.59	33.35	90
91	84.96	32.61	84.81	32.98	84.67	33.35	84.52	33.72	91
92	85.89	32.97	85.74	33.34	85.60	33.72	85.45	34.09	92
93	86.82	33.33	86.68	33.71	86.53	34.08	86.38	34.46	93
94	87.76	33.69	87.61	34.07	87.46	34.45	87.31	34.83	94
95	88.69	34.04	88.54	34.43	88.39	34.82	88.24	35.20	95
96	89.62	34.40	89.47	34.79	89.32	35.18	89.17	35.57	96
97	90.56	34.76	90.40	35.16	90.25	35.55	90.09	35.94	97
98	91.49	35.12	91.34	35.52	91.18	35.92	91.02	36.31	98
99	92.42	35.48	92.27	35.88	92.11	36.28	91.95	36 69	99
100	93.36	35.84	93.20	36.24	93.04	36.65	92.88	37.06	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	69 Deg.		68¾ Deg.		68½ Deg.		68¼ Deg.		

Distance.	22 Deg.		22¼ Deg.		22½ Deg.		22¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.93	0.37	0.93	0.38	0.92	0.38	0.92	0.39	1
2	1.85	0.75	1.85	0.76	1.85	0.77	1.84	0.77	2
3	2.78	1.12	2.78	1.14	2.77	1.15	2.77	1.16	3
4	3.71	1.50	3.70	1.51	3.70	1.53	3.69	1.55	4
5	4.64	1.87	4.63	1.89	4.62	1.91	4.61	1.93	5
6	5.56	2.25	5.55	2.27	5.54	2.30	5.53	2.32	6
7	6.49	2.62	6.48	2.65	6.47	2.68	6.46	2.71	7
8	7.42	3.00	7.40	3.03	7.39	3.06	7 38	3.09	8
9	8.34	3.37	8.33	3.41	8.31	3.44	8.30	3.48	9
10	9.27	3.75	9.26	3.79	9.24	3.83	9.22	3.87	10
11	10.20	4.12	10.18	4.17	10.16	4.21	10.14	4.25	11
12	11.13	4.50	11.11	4.54	11.09	4.59	11.07	4.64	12
13	12.05	4.87	12.03	4.92	12.01	4.97	11.99	5.03	13
14	12.98	5.24	12.96	5.30	12.93	5.36	12.91	5.41	14
15	13.91	5.62	13.88	5.68	13.86	5.74	13.83	5.80	15
16	14.83	5.99	14.81	6.06	14.78	6.12	14.76	6.19	16
17	15.76	6.37	15.73	6.44	15.71	6.51	15.68	6.57	17
18	16.69	6.74	16.66	6.82	16.63	6.89	16.60	6.96	18
19	17.62	7.12	17.59	7.19	17.55	7.27	17.52	7.35	19
20	18.54	7.49	18.51	7.57	18.48	7.65	18.44	7.73	20
21	13.47	7.87	19.44	7.95	19.40	8.04	19.37	8.12	21
22	20.40	8.24	20.36	8.33	20.33	8.42	20.29	8.51	22
23	21.33	8.62	21.29	8.71	21.25	8.80	21.21	8.89	23
24	22.25	8.99	22.21	9.09	22.17	9.18	22.13	9.28	24
25	23.18	9.37	23.14	9.47	23.10	9.57	23.05	9.67	25
26	24.11	9.74	24.06	9.84	24.02	9.95	23.98	10.05	26
27	25.03	10.11	24.99	10.22	24.94	10.33	24.90	10.44	27
28	25.96	10.49	25.92	10.60	25.87	10.72	25.82	10.83	28
29	26.89	10.86	26.84	10.98	26.79	11.10	26.74	11.21	29
30	27.82	11.24	27.77	11.36	27.72	11.48	27.67	11.60	30
31	28.74	11.61	28.69	11.74	28.64	11.86	28.59	11.99	31
32	29.67	11.99	29.62	12.12	29.56	12.25	29.51	12.37	32
33	30.60	12.36	30.54	12.50	30.49	12.63	30.43	12.76	33
34	31.52	12.74	31.47	12.87	31.41	13.01	31.35	13.15	34
35	32.45	13.11	32.39	13.25	32.34	13.39	32.28	13.53	35
36	33.38	13.49	33.32	13.63	33.26	13.78	33.20	13.92	36
37	34.31	13.86	34.24	14.01	34.18	14.16	34.12	14.31	37
38	35.23	14.24	35.17	14.39	35.11	14.54	35.04	14.70	38
39	36.16	14.61	36.10	14.77	36.03	14.92	35.97	15.08	39
40	37.09	14.98	37.02	15.15	36.96	15.31	36.89	15.47	40
41	38.01	15.36	37.95	15.52	37.88	15.69	37.81	15.86	41
42	38.94	15.73	38.87	15.90	38.80	16.07	38.73	16.24	42
43	39.87	16.11	39.80	16.28	39.73	16.46	39.65	16.63	43
44	40.80	16.48	40.72	16.66	40.65	16.84	40.58	17.02	44
45	41 72	16.86	41.65	17.04	41.57	17.22	41.50	17.40	45
46	42.65	17.23	42.57	17.42	12.50	17.60	42.42	17.79	46
47	43.58	17.61	43.50	17.80	43.42	17.99	43.34	18.18	47
48	44.50	17.98	44.43	18.18	44.35	18.37	44.27	18.56	48
49	45.43	18.36	45.35	18.55	45.27	18.75	45.19	18.95	49
50	46.36	18.73	46.28	18.93	46.19	19.13	46.11	19.34	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	68 Deg.		67¾ Deg.		67½ Deg.		67¼ Deg.		

Distance.	22 Deg.		22¼ Deg.		22½ Deg.		22¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	47.29	19.10	47.20	19.31	47.12	19.52	47.03	19.72	51
52	48.21	19.48	48.13	19.69	48.04	19.90	47.95	20.11	52
53	49.14	19.85	49.05	20.07	48.97	20.28	48.88	20.50	53
54	50.07	20.23	49.98	20.45	49.89	20.66	49.80	20.88	54
55	51.00	20.60	50.90	20.83	50.81	21.05	50.72	21.27	55
56	51.92	20.98	51.83	21.20	51.74	21.43	51.64	21.66	56
57	52.85	21.35	52.76	21.58	52.66	21.81	52.57	22.04	57
58	53.78	21.73	53.68	21.96	53.59	22.20	53.49	22.43	58
59	54.70	22.10	54.61	22.34	54.51	22.58	54.41	22.82	59
60	55.63	22.48	55.53	22.72	55.43	22.96	55.33	23.20	60
61	56.56	22.85	56.47	23.10	56.36	23.34	56.25	23.59	61
62	57.49	23.23	57.38	23.48	57.28	23.73	57.18	23.98	62
63	58.41	23.60	58.31	23.85	58.20	24.11	58.10	24.36	63
64	59.34	23.97	59.23	24.23	59.13	24.49	59.02	24.75	64
65	60.27	24.35	60.16	24.61	60.05	24.87	59.94	25.14	65
66	61.19	24.72	61.09	24.99	60.98	25.26	60.87	25.52	66
67	62.12	25.10	62.01	25.37	61.90	25.64	61.79	25.91	67
68	63.05	25.47	62.94	25.75	62.82	26.02	62.71	26.30	68
69	63.98	25.85	63.86	26.13	63.75	26.41	63.63	26.68	69
70	64.90	26.22	64.79	26.51	64.67	26.79	64.55	27.07	70
71	65.83	26.60	65.71	26.88	65.60	27.17	65.48	27.46	71
72	66.76	26.97	66.64	27.26	66.52	27.55	66.40	27.84	72
73	67.68	27.35	67.56	27.64	67.44	27.94	67.32	28.23	73
74	68.61	27.72	68.49	28.02	68.37	28.32	68.24	28.62	74
75	69.54	28.10	69.42	28.40	69.29	28.70	69.17	29.00	75
76	70.47	28.47	70.34	28.78	70.21	29.08	70.09	29.39	76
77	71.39	28.84	71.27	29.16	71.14	29.47	71.01	29.78	77
78	72.32	29.22	72.19	29.53	72.06	29.85	71.93	30.16	78
79	73.25	29.59	73.12	29.91	72.99	30.23	72.85	30.55	79
80	74.17	29.97	74.04	30.29	73.91	30.61	73.78	30.94	80
81	75.10	30.34	74.97	30.67	74.83	31.00	74.70	31.32	81
82	76.03	30.72	75.89	31.05	75.76	31.38	75.62	31.71	82
83	76.96	31.09	76.82	31.43	76.68	31.76	76.54	32.10	83
84	77.88	31.47	77.75	31.81	77.61	32.15	77.46	32.48	84
85	78.81	31.84	78.67	32.19	78.53	32.53	78.39	32.87	85
86	79.74	32.22	79.60	32.56	79.45	32.91	79.31	33.26	86
87	80.66	32.59	80.52	32.94	80.38	33.29	80.23	33.64	87
88	81.59	32.97	81.45	33.32	81.30	33.68	81.15	34.03	88
89	82.52	33.34	82.37	33.70	82.23	34.06	82.08	34.42	89
90	83.45	33.71	83.30	34.08	83.15	34.44	83.00	34.80	90
91	84.37	34.09	84.22	34.46	84.07	34.82	83.92	35.19	91
92	85.30	34.46	85.15	34.84	85.00	35.21	84.84	35.58	92
93	86.23	34.84	86.08	35.21	85.92	35.59	85.76	35.96	93
94	87.16	35.21	87.00	35.59	86.84	35.97	86.69	36.35	94
95	88.08	35.59	87.93	35.97	87.77	36.35	87.61	36.74	95
96	89.01	35.96	88.85	36.35	88.69	36.71	88.53	37.12	96
97	89.94	36.34	89.78	36.73	89.62	37.12	89.45	37.51	97
98	90.86	36.71	90.70	37.11	90.54	37.50	90.38	37.90	98
99	91.79	37.09	91.63	37.49	91.46	37.89	91.30	38.28	99
100	92.72	37.46	92.55	37.86	92.39	38.27	92.22	38.67	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	tance.
	68 Deg.		67¾ Deg.		67½ Deg.		67¼ Deg.		

Distance.	23 Deg.		23¼ Deg.		23½ Deg.		23¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.92	0.39	0.92	0.39	0.92	0.40	0.92	0.40	1
2	1.84	0.78	1.84	0.79	1.83	0.80	1.83	0.81	2
3	2.76	1.17	2.76	1.18	2.75	1.20	2.75	1.21	3
4	3.68	1.56	3.68	1.58	3.67	1.59	3.66	1.61	4
5	4.60	1.95	4.59	1.97	4.59	1.99	4.58	2.01	5
6	5.52	2.34	5.51	2.37	5.50	2.39	5.49	2.42	6
7	6.44	2.74	6.43	2.76	6.42	2.79	6.41	2.82	7
8	7.36	3.13	7.35	3.16	7.34	3.19	7.32	3.22	8
9	8.28	3.52	8.27	3.55	8.25	3.59	8.24	3.62	9
10	9.20	3.91	9.19	3.95	9.17	3.99	9.15	4.03	10
11	10.13	4.30	10.11	4.34	10.09	4.39	10.07	4.43	11
12	11.05	4.69	11.03	4.74	11.00	4.78	10.98	4.83	12
13	11.97	5.08	11.94	5.13	11.92	5.18	11.90	5.24	13
14	12.89	5.47	12.86	5.53	12.84	5.58	12.81	5.64	14
15	13.81	5.86	13.78	5.92	13.76	5.98	13.73	6.04	15
16	14.73	6.25	14.70	6.32	14.67	6.38	14.64	6.44	16
17	15.65	6.64	15.62	6.71	15.59	6.78	15.56	6.85	17
18	16.57	7.03	16.54	7.11	16.51	7.18	16.48	7.25	18
19	17.49	7.42	17.46	7.50	17.42	7.58	17.39	7.65	19
20	18.41	7.81	18.38	7.89	18.34	7.97	18.31	8.05	20
21	19.33	8.21	19.29	8.29	19.25	8.37	19.22	8.46	21
22	20.25	8.60	20.21	8.68	20.18	8.77	20.14	8.86	22
23	21.17	8.99	21.13	9.08	21.09	9.17	21.05	9.26	23
24	22.09	9.38	22.05	9.47	22.01	9.57	21.97	9.67	24
25	23.01	9.77	22.97	9.87	22.93	9.97	22.88	10.07	25
26	23.93	10.16	23.89	10.26	23.84	10.37	23.80	10.47	26
27	24.85	10.55	24.81	10.66	24.76	10.77	24.71	10.87	27
28	25.77	10.94	25.73	11.05	25.68	11.16	25.63	11.28	28
29	26.69	11.33	26.64	11.45	26.59	11.56	26.54	11.68	29
30	27.62	11.72	27.56	11.84	27.51	11.96	27.46	12.08	30
31	28.54	12.11	28.48	12.24	28.43	12.36	28.37	12.49	31
32	29.46	12.50	29.40	12.63	29.35	12.76	29.29	12.89	32
33	30.38	12.89	30.32	13.03	30.26	13.16	30.21	13.29	33
34	31.30	13.28	31.24	13.42	31.18	13.56	31.12	13.69	34
35	32.22	13.68	32.16	13.82	32.10	13.96	32.04	14.10	35
36	33.14	14.07	33.08	14.21	33.01	14.35	32.95	14.50	36
37	34.06	14.46	34.00	14.61	33.93	14.75	33.87	14.90	37
38	34.98	14.85	34.91	15.00	34.85	15.15	34.78	15.30	38
39	35.90	15.24	35.83	15.39	35.77	15.55	35.70	15.71	39
40	36.82	15.63	36.75	15.79	36.68	15.95	36.61	16.11	40
41	37.74	16.02	37.67	16.18	37.60	16.35	37.53	16.51	41
42	38.56	16.41	38.59	16.58	38.52	16.75	38.44	16.92	42
43	39.58	16.80	39.51	16.97	39.43	17.15	39.36	17.32	43
44	40.50	17.19	40.43	17.37	40.35	17.54	40.27	17.72	44
45	41.42	17.58	41.35	17.76	41.27	17.94	41.19	18.12	45
46	42.34	17.97	42.26	18.16	42.18	18.34	42.10	18.53	46
47	43.26	18.36	43.18	18.55	43.10	18.74	43.02	18.93	47
48	44.18	18.76	44.10	18.95	44.02	19.14	43.93	19.33	48
49	45.10	19.15	45.02	19.34	44.94	19.54	44.85	19.73	49
50	46.03	19.54	45.94	19.74	45.85	19.94	45.77	20.14	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	67 Deg		66¾ Deg.		66½ Deg.		66¼ Deg.		

Distance.	23 Deg		23¼ Deg.		23½ Deg.		23¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	46.95	19.93	46.86	20.13	46.77	20.34	46.68	20.54	51
52	47 87	20.32	47.78	20.53	47.69	20.73	47.60	20.94	52
53	48.79	20.71	48.70	20.92	48.60	21.13	48.51	21.35	53
54	49.71	21.10	49.61	21.32	49.52	21.53	49.43	21.75	54
55	50.63	21.49	50.53	21.71	50.44	21.93	50.34	22.15	55
56	51.55	21.88	51.45	22.11	51.36	22.33	51.26	22.55	56
57	52.47	22.27	52.37	22.50	52.27	22.73	52.17	22.96	57
58	53.39	22.66	53.29	22.90	53.19	23.13	53.09	23.36	58
59	54.31	23.05	54.21	23.29	54.11	23.53	54 00	23.76	59
60	55.23	23.44	55.13	23.68	55.02	23.92	54.92	24.16	60
61	56.15	23.83	56.05	24.08	55.94	24.32	55.83	24.57	61
62	57.07	24.23	56.97	24 47	56.86	24.72	56.75	24.97	62
63	57.99	24.62	57.88	24.87	57.77	25.12	57.66	25.37	63
64	58.91	25.01	58.80	25.26	58.69	25.52	58.58	25.78	64
65	59.83	25.40	59.72	25.66	59.61	25.92	59.50	26.18	65
66	60.75	25.79	60.64	26.05	60.53	26.32	60.41	26.58	66
67	61.67	26.18	61.56	26.45	61.44	26.72	61.33	26.98	67
68	62.59	26.57	62.48	26.84	62.36	27.11	62.24	27.39	68
69	63.51	26.96	63.40	27.24	63.28	27.51	63.16	27.79	69
70	64.44	27.35	64.32	27.63	64.19	27.91	64.07	28.19	70
71	65.36	27.74	65.23	28.03	65.11	28.34	64.99	28.59	71
72	66.28	28.13	66.15	28.42	66.03	28.71	65.90	29.00	72
73	67.20	28.52	67.07	28.82	66.95	29.11	66.82	29.40	73
74	68.12	28.91	67.99	29.21	67.86	29.51	67.73	29.80	74
75	69.04	29.30	68.91	29.61	68.78	29.91	68.65	30.21	75
76	69.96	29.70	69.83	30.00	69.70	30.30	69.56	30.61	76
77	70.88	30.09	70.75	30.40	70.61	30.70	70.48	31.01	77
78	71.80	30.48	71.67	30.79	71.53	31.10	71.39	31.41	78
79	72.72	30.87	72.58	31.18	72.45	31.50	72.31	31.82	79
80	73.64	31.26	73.50	31.58	73.36	31.90	73.22	32.22	80
81	74.56	31.65	74.42	31.97	74.28	32.30	74.14	32.62	81
82	75.48	32.04	75.34	32.37	75.20	32.70	75.06	33.03	82
83	76.40	32.43	76.26	32.76	76.12	33.10	75.97	33.43	83
84	77.32	32.82	77.18	33.16	77.03	33.49	76.89	33.83	84
85	78.24	33.21	78.10	33.55	77.95	33.89	77.80	34.23	85
86	79.16	33.60	79.02	33.95	78.87	34.29	78.72	34.64	86
87	80.08	33.99	79.93	34.34	79.78	34.69	79.63	35.04	87
88	81.00	34.38	80.85	34.74	80.70	35.09	80.55	35.44	88
89	81.92	34.78	81.77	35.13	81.62	35.49	81.46	35.84	89
90	82.85	35.17	82.69	35.53	82.54	35.89	82.38	36.25	90
91	83.77	35.56	83.61	35.92	83.45	36.29	83.29	36.65	91
92	84.69	35.95	84.53	36.32	84.37	36.68	84.21	37.05	92
93	85.61	36.34	85.45	36.71	85.29	37.08	85.12	37.46	93
94	86.53	36.73	86.37	37.11	86.20	37.48	86.04	37.86	94
95	87.45	37.12	87.29	37.50	87.12	37.88	86.95	38.26	95
96	88.37	37.51	88.20	37.90	88.04	38.28	87.87	38.66	96
97	89.29	37.90	89.12	38.29	88.95	38.68	88.79	39.07	97
98	90.21	38.29	90.04	38.68	89.87	39.08	89.70	39.47	98
99	91.13	38.68	90.96	39.08	90.79	39.48	90.62	39.87	99
100	92.05	39.07	91.88	39.47	91.71	39.87	91.53	40.27	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep	Lat.	Dep	Lat.	Distance.
	67 Deg.		66¾ Deg.		66½ Deg.		66¼ Deg.		

Distance.	24 Deg.		24¼ Deg.		24½ Deg.		24¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.91	0.41	0.91	0.41	0.91	0.41	0.91	0.42	1
2	1.83	0.81	1.82	0.82	1.82	0.83	1.82	0.84	2
3	2.74	1.22	2.74	1.23	2.73	1.24	2 72	1.26	3
4	3.65	1.63	3.65	1.64	3.64	1.66	3.63	1.67	4
5	4.57	2.03	4.56	2.05	4.55	2.07	4.54	2.09	5
6	5.48	2.44	5.47	2.46	5.46	2.49	5.45	2.51	6
7	6.39	2.85	6.38	2.87	6.37	2.90	6.36	2.93	7
8	7.31	3.25	7.29	3.29	7.28	3.32	7.27	3.35	8
9	8.22	3.66	8.21	3.70	8.19	3.73	8.17	3.77	9
10	9.14	4.07	9.12	4.11	9.10	4.15	9.08	4.19	10
11	10.05	4.47	10.03	4.52	10.01	4.56	9.99	4.61	11
12	10.96	4.88	10.94	4.93	10.92	4.98	10.90	5.02	12
13	11.88	5.29	11.85	5.34	11.83	5.39	11.81	5.44	13
14	12.79	5.69	12.76	5.75	12.74	5.81	12.71	5.86	14
15	13.70	6.10	13.68	6.16	13.65	6.22	13.62	6.28	15
16	14.62	6.51	14.59	6.57	14.56	6.64	14.53	6.70	16
17	15.53	6.92	15.50	6.98	15.47	7.05	15.44	7.12	17
18	16.44	7.32	16.41	7.39	16.38	7.46	16.35	7.54	18
19	17.36	7.73	17.32	7.80	17.29	7.88	17.25	7.95	19
20	18.27	8.13	18.24	8.21	18.20	8.29	18.16	8.37	20
21	19.18	8.54	19.15	8.63	19.11	8.71	19.07	8.79	21
22	20.10	8.95	20.06	9.04	20.02	9.12	19.98	9.21	22
23	21.01	9.35	20.97	9.45	20.93	9.54	20.89	9.63	23
24	21.93	9.76	21.88	9.86	21.84	9.95	21.80	10.05	24
25	22.84	10.17	22.79	10.27	22.75	10.37	22.70	10.47	25
26	23.75	10.58	23.71	10.68	23.66	10.78	23.61	10.89	26
27	24.67	10.98	24.62	11.09	24.57	11.20	24.52	11.30	27
28	25.58	11.39	25.53	11.50	25.48	11.61	25.43	11.72	28
29	26.49	11.80	26.44	11.91	26.39	12.03	26.34	12.14	29
30	27.41	12.20	27.35	12.32	27.30	12.44	27.24	12.56	30
31	28.32	12.61	28.26	12.73	28.21	12.86	28.15	12.98	31
32	29.23	13.02	29.18	13.14	29.12	13.27	29.06	13.40	32
33	30.15	13.42	30.09	13.55	30.03	13.68	29.97	13.82	33
34	31.06	13.83	31.00	13.96	30.94	14.10	30.88	14.23	34
35	31.97	14.24	31.91	14.38	31.85	14.51	31.78	14.65	35
36	32.89	14.64	32.82	14.79	32.76	14.93	32.69	15.07	36
37	33.80	15.05	33.74	15.20	33.67	15.34	33.60	15.49	37
38	34.71	15.46	34.65	15.61	34.58	15.76	34.51	15.91	38
39	35.63	15.86	35.56	16.02	35.49	16.17	35.42	16.33	39
40	36.54	16.27	36.47	16.43	36.40	16.59	36.33	16.75	40
41	37.46	16.68	37.38	16.84	37.31	17.00	37.23	17.16	41
42	38.37	17.08	38.29	17.25	38.22	17.42	38.14	17.58	42
43	39.28	17.49	39.21	17.66	39.13	17.83	39.05	18.00	43
44	40.20	17.90	40.12	18.07	40.04	18.25	39.96	18.42	44
45	41.11	18 30	41.03	18.48	40.95	18.66	40.87	18.84	45
46	42.02	18.71	41.94	18.89	41.86	19.08	41.77	19.26	46
47	42.94	19.12	42.85	19.30	42.77	19.49	42.68	19.68	47
48	43.85	19.52	43.76	19.71	43.68	19.91	43.59	20.10	48
49	44.76	19.93	44.68	20.13	44.59	20.32	44.50	20.51	49
50	45.68	20.34	45.59	20.54	45.50	20.73	45.41	20.93	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	66 Deg		65¾ Deg.		65½ Deg.		65¼ Deg		

Distance.	24 Deg.		24¼ Deg.		24½ Deg.		24¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	46.59	20.74	46.50	20.95	46.41	21.15	46.32	21.35	51
52	47.50	21.15	47.41	21.36	47.32	21.56	47.22	21.77	52
53	48.42	21.56	48.32	21.77	48.23	21.98	48.13	22.19	53
54	49.33	21.96	49.24	22.18	49.14	22.39	49.04	22.61	54
55	50.24	22.37	50.15	22.59	50.05	22.81	49.95	23.03	55
56	51.16	22.78	51.06	23.00	50.96	23.22	50.86	23.44	56
57	52.07	23.18	51.97	23.41	51.87	23.64	51.76	23.86	57
58	52.99	23.59	52.88	23.82	52.78	24.05	52.67	24.28	58
59	53.90	24.00	53.79	24.23	53.69	24.47	53.58	24.70	59
60	54.81	24.40	54.71	24.64	54.60	24.88	54.49	25.12	60
61	55.73	24.81	55.62	25.05	55.51	25.30	55.40	25.54	61
62	56.64	25.22	56.53	25.46	56.42	25.71	56.30	25.96	62
63	57.55	25.62	57.44	25.88	57.33	26.13	57.21	26.38	63
64	58.47	26.03	58.35	26.29	58.24	26.54	58.12	26.79	64
65	59.38	26.44	59.26	26.70	59.15	26.96	59.03	27.21	65
66	60.29	26.84	60.18	27.11	60.06	27.37	59.94	27.63	66
67	61.21	27.25	61.09	27.52	60.97	27.78	60.85	28.05	67
68	62.12	27.66	62.00	27.93	61.88	28.20	61.75	28.47	68
69	63.03	28.06	62.91	28.34	62.79	28.61	62.66	28.89	69
70	63.95	28.47	63.82	28.75	63.70	29.03	63.57	29.31	70
71	64.86	28.88	64.74	29.16	64.61	29.44	64.48	29.72	71
72	65.78	29.28	65.65	29.57	65.52	29.86	65.39	30.14	72
73	66.69	29.69	66.56	29.98	66.43	30.27	66.29	30.56	73
74	67.60	30.10	67.47	30.39	67.34	30.69	67.20	30.98	74
75	68.52	30.51	68.38	30.80	68.25	31.10	68.11	31.40	75
76	69.43	30.91	69.29	31.21	69.16	31.52	69.02	31.82	76
77	70.34	31.32	70.21	31.63	70.07	31.93	69.93	32.24	77
78	71.26	31.73	71.12	32.04	70.98	32.35	70.84	32.66	78
79	72.17	32.13	72.03	32.45	71.89	32.76	71.74	33.07	79
80	73.08	32.54	72.94	32.86	72.80	33.18	72.65	33.49	80
81	74.00	32.95	73.85	33.27	73.71	33.59	73.56	33.91	81
82	74.91	33.35	74.76	33.68	74.62	34.00	74.47	34.33	82
83	75.82	33.76	75.68	34.09	75.53	34.42	75.38	34.75	83
84	76.74	34.17	76.59	34.50	76.44	34.83	76.28	35.17	84
85	77.65	34.57	77.50	34.91	77.35	35.25	77.19	35.59	85
86	78.56	34.98	78.41	35.32	78.26	35.66	78.10	36.00	86
87	79.48	35.39	79.32	35.73	79.17	36.08	79.01	36.42	87
88	80.39	35.79	80.24	36.14	80.08	36.49	79.92	36.84	88
89	81.31	36.20	81.15	36.55	80.99	36.91	80.82	37.26	89
90	82.22	36.61	82.06	36.96	81.90	37.32	81.73	37.68	90
91	83.13	37.01	82.97	37.38	82.81	37.74	82.64	38.10	91
92	84.05	37.42	83.88	37.79	83.72	38.15	83.55	38.52	92
93	84.96	37.83	84.79	38.20	84.63	38.57	84.46	38.94	93
94	85.87	38.22	85.71	38.61	85.54	38.98	85.37	39.35	94
95	86.79	38.64	86.62	39.02	86.45	39.40	86.27	39.77	95
96	87.70	39.05	87.53	39.43	87.36	39.81	87.18	40.19	96
97	88.61	39.45	88.44	39.84	88.27	40.23	88.09	40.61	97
98	89.53	39.86	89.35	40.25	89.18	40.64	89.00	41.03	98
99	90.44	40.27	90.26	40.66	90.09	41.05	89.91	41.45	99
100	91.35	40.67	91.18	41.07	91.00	41.47	90.81	41.87	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	66 Deg.		65¾ Deg.		65½ Deg.		65¼ Deg.		

Distance.	25 Deg.		25¼ Deg.		25½ Deg		25¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.91	0.42	0.90	0.43	0.90	0.43	0.90	0.43	1
2	1.81	0.85	1.81	0.85	1.81	0.86	1.80	0.87	2
3	2.72	1.27	2.71	1.28	2.71	1.29	2.70	1.30	3
4	3.63	1.69	3.62	1.71	3.61	1.72	3.60	1.74	4
5	4.53	2.11	4.52	2.13	4.51	2.15	4.50	2.17	5
6	5.44	2.54	5.43	2.56	5.42	2.58	5.40	2.61	6
7	6.34	2.96	6.33	2.99	6.32	3.01	6.30	3.04	7
8	7.25	3.38	7.24	3.41	7.22	3.44	7.21	3.48	8
9	8.16	3.80	8.14	3.84	8.12	3.87	8.11	3.91	9
10	9.06	4.23	9.04	4.27	9.03	4.31	9.01	4.34	10
11	9.97	4.65	9.95	4.69	9.93	4.74	9.91	4.78	11
12	10.88	5.07	10.85	5.12	10.83	5.17	10.81	5.21	12
13	11.78	5.49	11.76	5.55	11.73	5.60	11.71	5.65	13
14	12.69	5.92	12.66	5.97	12.64	6.03	12.61	6.08	14
15	13.59	6.34	13.57	6.40	13.54	6.46	13.51	6.52	15
16	14.50	6.76	14.47	6.83	14.44	6.89	14.41	6.95	16
17	15.41	7.18	15.38	7.25	15.34	7.32	15.31	7.39	17
18	16.31	7.61	16.28	7.68	16.25	7.75	16.21	7.82	18
19	17.22	8.03	17.18	8.10	17.15	8.18	17.11	8.25	19
20	18.13	8.45	18.09	8.53	18.05	8.61	18.01	8.69	20
21	19.03	8.87	18.99	8.96	18.95	9.04	18.91	9.12	21
22	19.94	9.30	19.90	9.38	19.86	9.47	19.82	9.56	22
23	20.85	9.72	20.80	9.81	20.76	9.90	20.72	9.99	23
24	21.75	10.14	21.71	10.24	21.66	10.33	21.62	10.13	24
25	22.66	10.57	22.61	10.66	22.56	10.76	22.52	10.86	25
26	23.56	10.99	23.52	11.09	23.47	11.19	23.42	11.30	26
27	24.47	11.41	24.42	11.52	24.37	11.62	24.32	11.73	27
28	25.38	11.83	25.32	11.94	25.27	12.05	25.22	12.16	28
29	26.28	12.26	26.23	12.37	26.17	12.48	26.12	12.60	29
30	27.19	12.68	27.13	12.80	27.08	12.92	27.02	13.03	30
31	28.10	13.10	28.04	13.22	27.98	13.35	27.92	13.47	31
32	29.00	13.52	28.94	13.65	28.88	13.78	28.82	13.90	32
33	29.91	13.95	29.85	14.08	29.79	14.21	29.72	14.34	33
34	30.81	14.37	30.75	14.50	30.69	14.64	30.62	14.77	34
35	31.72	14.79	31.66	14.93	31.59	15.07	31.52	15.21	35
36	32.63	15.21	32.56	15.36	32.49	15.50	32.43	15.64	36
37	33.53	15.64	33.46	15.78	33.40	15.93	33.33	16.07	37
38	34.44	16.06	34.37	16.21	34.30	16.36	34.23	16.51	38
39	35.35	16.48	35.27	16.64	35.20	16.79	35.13	16.94	39
40	36.25	16.90	36.18	17.06	36.10	17.22	36.03	17.38	40
41	37.16	17.33	37.08	17.49	37.01	17.65	36.93	17.81	41
42	38.06	17.75	37.99	17.92	37.91	18.08	37.83	18.25	42
43	38.97	18.17	38.89	18.34	38.81	18.51	38.73	18.68	43
44	39.88	18.60	39.80	18.77	39.71	18.94	39.63	19.12	44
45	40.78	19.02	40.70	19.20	40.62	19.37	40.53	19.55	45
46	41.69	19.44	41.60	19.62	41.52	19.80	41.43	19.98	46
47	42.60	19.86	42.51	20.05	42.42	20.23	42.33	20.42	47
48	43.50	20.29	43.41	20.48	43.32	20.66	43.23	20.85	48
49	44.41	20.71	44.32	20.90	44.23	21.10	44.13	21.29	49
50	45.32	21.13	45.22	21.33	45.13	21.53	45.03	21.72	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	65 Deg.		64¾ Deg.		64½ Deg.		64¼ Deg.		

Distance.	25 Deg.		25¼ Deg.		25½ Deg.		25¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	46.22	21.55	46.13	21.75	46.03	21.96	45.94	22.16	51
52	47.13	21.98	47.03	22.18	46.93	22.39	46.84	22.59	52
53	48.03	22.40	47.94	22.61	47.84	22.82	47.74	23.03	53
54	48.94	22.82	48.84	23.03	48.74	23.25	48.64	23.46	54
55	49.85	23.24	49.74	23.46	49.64	23.68	49.54	23.89	55
56	50.75	23.67	50.65	23.89	50.54	24.11	50.44	24.33	56
57	51 66	24.09	51.55	24.31	51.45	24.54	51.34	24.76	57
58	52.57	24.51	52.46	24.74	52.35	24.97	52.24	25.20	58
59	53 47	24.93	53.36	25.17	53.25	25.40	53.14	25.63	59
60	54 38	25.36	54.27	25.59	54.16	25.83	54.04	26.07	60
61	55.28	25.78	55.17	26.02	55.06	26.26	54.94	26.50	61
62	56.19	26.20	56.08	26.45	55.96	26.69	55.84	26.91	62
63	57.10	26 62	56.98	26.87	56.86	27.12	56.74	27.37	63
64	58.00	27.05	57.89	27.30	57.77	27.55	57.64	27.80	64
65	58.91	27.47	58.79	27.73	58.67	27.98	58.55	28.24	65
66	59.82	27.89	59.69	28.15	59.57	28.41	59.45	28.67	66
67	60.72	28.32	60.60	28.58	60.47	28.84	60.35	29.11	67
68	61.63	28.74	61.50	29.01	61.38	29.27	61.25	29.54	68
69	62.54	29.16	62.41	29.43	62.28	29.71	62.15	29.98	69
70	63.44	29.58	63.31	29.86	63.18	30.14	63.05	30.41	70
71	64.35	30.01	64.22	30.29	64.08	30.57	63.95	30.85	71
72	65.25	30.43	65.12	30.71	64.99	31.00	64.85	31.28	72
73	66.16	30.85	66.03	31.14	65.89	31.43	65.75	31.71	73
74	67.07	31.27	66.93	31.57	66.79	31.86	66.65	32.15	74
75	67.97	31.70	67.83	31.99	67.69	32.29	67.55	32.58	75
76	68.88	32.12	68.74	32.42	68.60	32.72	68.45	33.02	76
77	69.79	32.54	69.64	32.85	69.50	33.15	69.35	33.45	77
78	70.69	32.96	70.55	33.27	70.40	33.58	70.25	33.89	78
79	71.60	33.39	71.45	33.70	71.30	34.01	71.16	34.32	79
80	72.50	33.81	72.36	34.13	72.21	34.44	72.06	34.76	80
81	73.41	34.23	73.26	34.55	73.11	34.87	72.96	35.19	81
82	74.32	34.65	74.17	34.98	74.01	35.30	73.86	35.62	82
83	75.22	35.08	75.07	35.41	74.91	35.73	74.76	36.06	83
84	76.13	35.50	75.97	35.83	75.82	36.16	75.66	36.49	84
85	77.04	35.92	76.88	36.26	76.72	36.59	76.56	36.93	85
86	77.94	36.35	77.78	36.68	77.62	37.02	77.46	37.36	86
87	78.85	36.77	78.69	37.11	78.52	37.45	78.36	37.80	87
88	79.76	37.19	79.59	37.54	79.43	37.88	79.26	38.23	88
89	80.66	37.61	80.50	37.96	80.33	38.32	80.16	38.67	89
90	81.57	38.04	81.40	38.39	81.23	38.75	81.06	39.10	90
91	82.47	38.46	82.31	38.82	82.14	39.18	81.96	39.53	91
92	83.38	38.88	83.21	39.24	83.04	39.61	82.86	39.97	92
93	84.29	39.30	84.11	39.67	83.94	40.04	83.76	40.40	93
94	85.19	39.73	85.02	40.10	84.84	40.47	84.67	40.84	94
95	86.10	40.15	85.92	40.52	85.75	40.90	85 57	41.27	95
96	87.01	40.57	86.83	40.95	86.65	41.33	86 47	41.71	96
97	87.91	40.99	87.73	41.38	87.55	41.76	87.37	42.14	97
98	88.82	41.42	88.64	41.80	88.45	42.19	88.27	42.58	98
99	89.72	41.84	89.54	42.23	89.36	42.62	99.17	43.01	99
100	90.63	42.26	90.45	42.66	90.26	43.05	90.07	43 44	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	65 Deg.		64¾ Deg.		64½ Deg.		64¼ Deg.		

Distance.	26 Deg.		26¼ Deg.		26½ Deg.		26¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.90	0.44	0.90	0.44	0.89	0.45	0.89	0.45	1
2	1.80	0.88	1.79	0.88	1.79	0.89	1.79	0.90	2
3	2.70	1.32	2.69	1.33	2.68	1.34	2.68	1.35	3
4	3.60	1.75	3.59	1.77	3.58	1.78	3.57	1.80	4
5	4.49	2.19	4.48	2.21	4.47	2.23	4.46	2.25	5
6	5.39	2.63	5.38	2.65	5.37	2.68	5.36	2.70	6
7	6.29	3.07	6.28	3.10	6.26	3.12	6.25	3.15	7
8	7.19	3.51	7.17	3.54	7.16	3.57	7.14	3.60	8
9	8.09	3.95	8.07	3.98	8.05	4.02	8.04	4.05	9
10	8.99	4.38	8.97	4.42	8.95	4.46	8.93	4.50	10
11	9.89	4.82	9.87	4.87	9.84	4.91	9.82	4.95	11
12	10.79	5.26	10.76	5.31	10.74	5.35	10.72	5.40	12
13	11.68	5.70	11.66	5.75	11.63	5.80	11.61	5.85	13
14	12.58	6.14	12.56	6.19	12.53	6.25	12.50	6.30	14
15	13.48	6.58	13.45	6.63	13.42	6.69	13.39	6.75	15
16	14.38	7.01	14.35	7.08	14.32	7.14	14.29	7.20	16
17	15.28	7.45	15.25	7.52	15.21	7.59	15.18	7.65	17
18	16.18	7.89	16.14	7.96	16.11	8.03	16.07	8.10	18
19	17.08	8.33	17.04	8.40	17.00	8.48	16.97	8.55	19
20	17.98	8.77	17.94	8.85	17.90	8.92	17.86	9.00	20
21	18.87	9.21	18.83	9.29	18.79	9.37	18.75	9.45	21
22	19.77	9.64	19.73	9.73	19.69	9.82	19.65	9.90	22
23	20.67	10.08	20.63	10.17	20.58	10.26	20.54	10.35	23
24	21.57	10.52	21.52	10.61	21.48	10.71	21.43	10.80	24
25	22.47	10.96	22.42	11.06	22.37	11.15	22.32	11.25	25
26	23.37	11.40	23.32	11.50	23.27	11.60	23.22	11.70	26
27	24.27	11.84	24.22	11.94	24.16	12.05	24.11	12.15	27
28	25.17	12.27	25.11	12.38	25.06	12.49	25.00	12.60	28
29	26.06	12.71	26.01	12.83	25.95	12.94	25.90	13.05	29
30	26.96	13.15	26.91	13.27	26.85	13.39	26.79	13.50	30
31	27.86	13.59	27.80	13.71	27.74	13.83	27.68	13.95	31
32	28.76	14.03	28.70	14.15	28.64	14.28	28.58	14.40	32
33	29.66	14.47	29.60	14.60	29.53	14.72	29.47	14.85	33
34	30.56	14.90	30.49	15.04	30.43	15.17	30.36	15.30	34
35	31.46	15.34	31.39	15.48	31.32	15.62	31.25	15.75	35
36	32.36	15.78	32.29	15.92	32.22	16.06	32.15	16.20	36
37	33.26	16.22	33.18	16.36	33.11	16.51	33.04	16.65	37
38	34.15	16.66	34.08	16.81	34.01	16.96	33.93	17.10	38
39	35.05	17.10	34.98	17.25	34.90	17.40	34.83	17.55	39
40	35.95	17.53	35.87	17.69	35.80	17.85	35.72	18.00	40
41	36.85	17.97	36.77	18.13	36.69	18.29	36.61	18.45	41
42	37.75	18.41	37.67	18.58	37.59	18.74	37.51	18.90	42
43	38.65	18.85	38.57	19.02	38.48	19.19	38.40	19.35	43
44	39.55	19.29	39.46	19.46	39.38	19.63	39.29	19.80	44
45	40.45	19.73	40.36	19.90	40.27	20.08	40.18	20.25	45
46	41.34	20.17	41.26	20.35	41.17	20.53	41.08	20.70	46
47	42.24	20.60	42.15	20.79	42.06	20.97	41.97	21.15	47
48	43.14	21.04	43.05	21.23	42.96	21.42	42.86	21.60	48
49	44.04	21.48	43.95	21.67	43.85	21.86	43.76	22.05	49
50	44.94	21.92	44.84	22.11	44.75	22.31	44.65	22.50	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	64 Deg.		63¾ Deg.		63½ Deg.		63¼ Deg.		

Distance.	26 Deg.		26¼ Deg.		26½ Deg.		26¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	45.84	22.36	45.74	22.56	45.64	22.76	45.54	22.96	51
52	46.74	22.80	46.64	23.00	46.54	23.20	46.43	23.41	52
53	47.64	23.23	47.53	23.44	47.43	23.65	47.33	23.86	53
54	48.53	23.67	48.43	23.88	48.33	24.09	48.22	24.31	54
55	49.43	24.11	49.33	24.33	49.22	24.54	49.11	24.76	55
56	50.33	24.55	50.22	24.77	50.12	24.99	50.01	25.21	56
57	51.23	24.99	51.12	25.21	51.01	25.43	50.90	25.66	57
58	52.13	25.43	52.02	25.65	51.91	25.68	51.79	26.11	58
59	53.03	25.86	52.92	26.09	52.80	26.33	52.69	26.56	59
60	53.93	26.30	53.81	26.54	53.70	26.77	53.58	27.01	60
61	54.83	26.74	54.71	26.98	54.59	27.22	54.47	27.46	61
62	55.73	27.18	55.61	27.42	55.49	27.66	55.36	27.91	62
63	56.62	27.62	56.50	27.86	56.38	28.11	56.26	28.36	63
64	57.52	28.06	57.40	28.31	57.28	28.56	57.15	28.81	64
65	58.42	28.49	58.30	28.75	58.17	29.00	58.04	29.26	65
66	59.32	28.93	59.19	29.19	59.07	29.45	58.94	29.71	66
67	60.22	29.37	60.09	29.63	59.96	29.90	59.83	30.16	67
68	61.12	29.81	60.99	30.08	60.86	30.34	60.72	30.61	68
69	62.02	30.25	61.88	30.52	61.75	30.79	61.62	31.06	69
70	62.92	30.69	62.78	30.96	62.65	31.23	62.51	31.51	70
71	63.81	31.12	63.68	31.40	63.54	31.68	63.40	31.96	71
72	64.71	31.56	64.57	31.84	64.44	32.13	64.29	32.41	72
73	65.61	32.00	65.47	32.29	65.33	32.57	65.19	32.86	73
74	66.51	32.44	66.37	32.73	66.23	33.02	66.08	33.31	74
75	67.41	32.88	67.27	33.17	67.12	33.46	66.97	33.76	75
76	68.31	33.32	68.16	33.61	68.01	33.91	67.87	34.21	76
77	69.21	33.75	69.06	34.06	68.91	34.36	68.76	34.66	77
78	70.11	34.19	69.96	34.50	69.80	34.80	69.65	35.11	78
79	71.00	34.63	70.85	34.94	70.70	35.25	70.55	35.56	79
80	71.90	35.07	71.75	35.38	71.59	35.70	71.44	36.01	80
81	72.80	35.51	72.65	35.83	72.49	36.14	72.33	36.46	81
82	73.70	35.95	73.54	36.27	73.38	36.59	73.22	36.91	82
83	74.60	36.38	74.44	36.71	74.28	37.03	74.12	37.36	83
84	75.50	36.82	75.34	37.15	75.17	37.48	75.01	37.81	84
85	76.40	37.26	76.23	37.59	76.07	37.93	75.90	38.26	85
86	77.30	37.70	77.13	38.04	76.96	38.37	76.80	38.71	86
87	78.20	38.14	78.03	38.48	77.86	38.82	77.69	39.16	87
88	79.09	38.58	78.92	38.92	78.75	39.27	78.58	39.61	88
89	79.99	39.01	79.82	39.36	79.65	39.71	79.48	40.06	89
90	80.89	39.45	80.72	39.81	80.54	40.16	80.37	40.51	90
91	81.79	39.89	81.62	40.25	81.44	40.60	81.26	40.96	91
92	82.69	40.33	82.51	40.69	82.33	41.05	82.15	41.41	92
93	83.59	40.77	83.41	41.13	83.23	41.50	83.05	41.86	93
94	84.49	41.21	84.31	41.58	84.12	41.94	83.94	42.31	94
95	85.39	41.65	85.20	42.02	85.02	42.39	84.83	42.76	95
96	86.28	42.08	86.10	42.46	85.91	42.83	85.73	43.21	96
97	87.18	42.52	87.00	42.90	86.81	43.28	86.62	43.66	97
98	88.08	42.96	87.89	43.34	87.70	43.73	87.51	44.11	98
99	88.98	43.40	88.79	43.79	88.60	44.17	88.40	44.56	99
100	89.88	43.84	89.62	44.23	89.49	44.62	89.30	45.01	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	64 Deg.		63¾ Deg.		63½ Deg.		63¼ Deg.		

Distance.	27 Deg.		27¼ Deg.		27½ Deg.		27¾ Deg.		Distance.
	Lat.	Dep.	Lat	Dep.	Lat.	Dep.	Lat	Dep.	
1	0.89	0.45	0.89	0.46	0.89	0.46	0.88	0.47	1
2	1.78	0.91	1.78	0.92	1.77	0.92	1.77	0.93	2
3	2.67	1.36	2.67	1.37	2.66	1.39	2 65	1.40	3
4	3.56	1 82	3.56	1.83	3.55	1.85	3.54	1.86	4
5	4.45	2 27	4.45	2.29	4.44	2.31	4.42	2.33	5
6	5.35	2.72	5.33	2.75	5.32	2.77	5.31	2.79	6
7	6.24	3.18	6.22	3.21	6.21	3.23	6.19	3.26	7
8	7.13	3.63	7.11	3.66	7.10	3.69	7.08	3.72	8
9	8.02	4.09	8.00	4.12	7.98	4.16	7.96	4.19	9
10	8.91	4.54	8.89	4.58	8.87	4.62	8.85	4.66	10
11	9.80	4.99	9.78	5.04	9.76	5.08	9.73	5.12	11
12	10.69	5.45	10.67	5.49	10.64	5.54	10.62	5.59	12
13	11.58	5.90	11.56	5.95	11.53	6.00	11.50	6.05	13
14	12.47	6.36	12.45	6.41	12.42	6.46	12.39	6.52	14
15	13.37	6.81	13.34	6.87	13.31	6.93	13.27	6.98	15
16	14.26	7.26	14.22	7.33	14.19	7.39	14.16	7.45	16
17	15.15	7.72	15.11	7.78	15.08	7.85	15.04	7.92	17
18	16.04	8.17	16.00	8.24	15.97	8.31	15.93	8.38	18
19	16.93	8.63	16.89	8.70	16.85	8.77	16.81	8.85	19
20	17.82	9.08	17.78	9.16	17.74	9.23	17.70	9.31	20
21	18.71	9.53	18.67	9.62	18.63	9.70	18.58	9.78	21
22	19.60	9.99	19.56	10.07	19.51	10.16	19.47	10.24	22
23	20.49	10.44	20.45	10.53	20.10	10.62	20.35	10.71	23
24	21.38	10.90	21.34	10.99	21.29	11.08	21.24	11.17	24
25	22.28	11.35	22.23	11.45	22.18	11.54	22.12	11.64	25
26	23.17	11.80	23.11	11.90	23.06	12.01	23.01	12.11	26
27	24.06	12.26	24.00	12.36	23.95	12.47	23.89	12.57	27
28	24.95	12.71	24.89	12.82	24.84	12.93	24.78	13.04	28
29	25.84	13.17	25.78	13.28	25.72	13.39	25.66	13.50	29
30	26.73	13.62	26.67	13.74	26.61	13.85	26.55	13.97	30
31	27.62	14.07	27.56	14.19	27.50	14.31	27.43	14.43	31
32	28.51	14.53	28.45	14.65	28.38	14.78	28.32	14.90	32
33	29.40	14.98	29.34	15.11	29.27	15.24	29.20	15.37	33
34	30.29	15.44	30.23	15.57	30.16	15.70	30.09	15.83	34
35	31.19	15.89	31.12	16.03	31.05	16.16	30.97	16.30	35
36	32.08	16.34	32.00	16.48	31.93	16.62	31.86	16.76	36
37	32.97	16.80	32.89	16.94	32.82	17.08	32.74	17.23	37
38	33.86	17.25	33.78	17.40	33.71	17.55	33.63	17.69	38
39	34.75	17.71	34.67	17.86	34.59	18.01	34.51	18.16	39
40	35.64	18.16	35.56	18.31	35.48	18.47	35.40	18.62	40
41	36.53	18.61	36.45	18.77	36.37	18.93	36.28	19.09	41
42	37.42	19.07	37.34	19.23	37.25	19.39	37.17	19.56	42
43	38.31	19.52	38.23	19.69	38.14	19.86	38.05	20.02	43
44	39.20	19.98	39.12	20.15	39.03	20.32	38.94	20 49	44
45	40.10	20.43	40.01	20.60	39.92	20.78	39.82	20 95	45
46	40.99	20.88	40.89	21.06	40.80	21.24	40.71	21.42	46
47	41.88	21.34	41.78	21.52	41.69	21.70	41.59	21.88	47
48	42.77	21.79	42.67	21.98	42.58	22.16	42.48	22.35	48
49	43.66	22.25	43.56	22.44	43.46	22.63	43.36	22.82	49
50	44.55	22.70	44.45	22.89	44.35	23.09	44.25	23 28	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat	Dep.	Lat.	Distance.
	63 Deg.		62¾ Deg.		62½ Deg		62¼ Deg.		

Distance.	27 Deg.		27¼ Deg.		27½ Deg.		27¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	45.41	23.15	45.34	23.35	45.24	23.55	45.13	23.75	51
52	46.33	23.61	46.23	23.81	46.12	24.01	46.02	24.21	52
53	47.22	24.06	47.12	24.27	47.01	24.47	46.90	24.68	53
54	48.11	24.52	48.01	24.73	47.90	24.93	47.79	25.14	54
55	49.01	24.97	48.90	25.18	48.79	25.40	48.67	25.61	55
56	49.90	25.42	49.78	25.64	49.67	25.86	49.56	26.07	56
57	50.79	25.88	50.67	26.10	50.56	26.32	50.44	26.54	57
58	51.68	26.33	51.56	26.56	51.45	26.78	51.33	27.01	58
59	52.57	26.79	52.45	27.01	52.33	27.24	52.21	27.47	59
60	53.46	27.24	53.34	27.47	53.22	27.70	53.10	27.94	60
61	54.35	27.69	54.23	27.93	54.11	28.17	53.98	28.40	61
62	55.24	28.15	55.12	28.39	54.99	28.63	54.87	28.87	62
63	56.13	28.60	56.01	28.85	55.88	29.09	55.75	29.33	63
64	57.02	29.06	56.90	29.30	56.77	29.55	56.64	29.80	64
65	57 92	29.51	57.79	29.76	57.66	30.01	57.52	30.26	65
66	58.81	29.96	58.68	30.22	58.54	30.48	58.41	30.73	66
67	59.70	30.42	59.56	30.68	59.43	30.94	59.29	31.20	67
68	60.59	30.87	60.45	31.14	60.32	31.40	60.18	31.66	68
69	61.48	31.33	61.34	31.59	61.20	31.86	61.06	32.13	69
70	62.37	31.78	62.23	32.05	62.09	32.32	61.95	32.59	70
71	63.26	32.23	63.12	32.51	62.98	32.78	62.83	33.06	71
72	64.15	32.69	64.01	32.97	63.86	33.25	63.72	33.52	72
73	65.04	33.14	64.90	33.42	64.75	33.71	64.60	33.99	73
74	65.93	33.60	65.79	33.88	65.64	34.17	65.49	34.46	74
75	66.83	34.05	66.68	34.34	66.53	34.63	66.37	34.92	75
76	67.72	34.50	67.57	34.80	67.41	35.09	67.26	35.39	76
77	68.61	34.96	68.45	35.26	68.30	35.55	68.14	35.85	77
78	69.50	35.41	69.34	35.71	69.19	36.02	69.03	36.32	78
79	70.39	35.87	70.23	36.17	70.07	36.48	69.91	36.78	79
80	71.28	36.32	71.12	36.63	70.96	36.94	70.80	37.25	80
81	72.17	36.77	72.01	37.09	71.85	37.40	71.68	37.71	81
82	73.06	37.23	72.90	37.55	72.73	37.86	72.57	38.18	82
83	73.95	37.68	73.79	38.00	73.62	38.33	73.45	38.65	83
84	74.84	38.14	74.68	38.46	74.51	38.79	74.34	39.11	84
85	75.74	38.59	75.57	38.92	75.40	39.25	75.22	39.58	85
86	76.63	39.04	76.46	39.38	76.28	39.71	76.11	40.04	86
87	77.52	39.50	77.34	39.83	77.17	40.17	76.99	40.51	87
88	78 41	39.95	78.23	40.29	78.06	40.63	77.88	40.97	88
89	79.30	40.41	79.12	40.75	78.94	41.10	78.76	41.44	89
90	80.19	40.86	80.01	41.21	79.83	41.56	79.65	41.91	90
91	81.08	41.31	80.90	41.67	80.72	42.02	80.53	42.37	91
92	81 97	41.77	81.79	42.12	81.60	42.48	81.42	42.84	92
93	82.86	42.22	82.68	42.58	82.49	42.94	82.30	43.30	93
94	83.75	42.68	83.57	43.04	83.38	43.40	83.19	43.77	94
95	84.65	43.13	84.46	43.50	84.27	43.87	84.07	44.23	95
96	85.54	43.58	85.35	43.96	85.15	44.33	84.96	44.70	96
97	86.43	44.04	86.23	44.41	86.04	44.79	85.84	45.16	97
98	87.32	44.49	87.12	44.87	86.93	45.25	86.73	45.63	98
99	88.21	44.95	88.01	45.33	87.81	45.71	87.61	46.10	99
100	89.10	45.40	88.90	45.79	88.70	46.17	88.50	46.56	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	63 Deg.		62¾ Deg.		62½ Deg.		62¼ Deg.		

Distance.	28 Deg.		28¼ Deg.		28½ Deg.		28¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat	Dep.	
1	0.88	0.47	0.88	0.47	0.88	0.48	0.88	0.48	1
2	1.77	0.94	1.76	0.95	1.76	0.95	1.75	0.96	2
3	2.65	1.41	2.64	1.42	2.64	1.43	2.63	1.44	3
4	3.53	1.88	3.52	1.89	3.52	1.91	3.51	1.92	4
5	4.41	2.35	4.40	2.37	4.39	2.39	4.38	2.40	5
6	5.30	2.82	5.29	2.84	5.27	2.86	5.26	2.89	6
7	6.18	3.29	6.17	3.31	6.15	3.34	6.14	3.37	7
8	7.06	3.76	7.05	3.79	7.03	3.82	7.01	3.85	8
9	7.95	4.23	7.93	4.26	7.91	4.29	7.89	4.33	9
10	8.83	4.69	8.81	4.73	8.79	4.77	8.77	4.81	10
11	9.71	5.16	9.69	5.21	9.67	5.25	9.64	5.29	11
12	10.60	5.63	10.57	5.68	10.55	5.73	10.52	5.77	12
13	11.48	6.10	11.45	6.15	11.42	6.20	11.40	6.25	13
14	12.36	6.57	12.33	6.63	12.30	6.68	12.27	6.73	14
15	13.24	7.04	13.21	7.10	13.18	7.16	13.15	7.21	15
16	14.13	7.51	14.09	7.57	14.06	7.63	14.03	7.70	16
17	15.01	7.98	14.98	8.05	14.94	8.11	14.90	8.18	17
18	15.89	8.45	15.86	8.52	15.82	8.59	15.78	8.66	18
19	16.78	8.92	16.74	8.99	16.70	9.07	16.66	9.14	19
20	17.66	9.39	17.62	9.47	17.58	9.54	17.53	9.62	20
21	18.54	9.86	18.50	9.94	18.46	10.02	18.41	10.10	21
22	19.42	10.33	19.38	10.41	19.33	10.50	19.29	10.58	22
23	20.31	10.80	20.26	10.89	20.21	10.97	20.16	11.06	23
24	21.19	11.27	21.14	11.36	21.09	11.45	21.04	11.54	24
25	22.07	11.74	22.02	11.83	21.97	11.93	21.92	12.02	25
26	22.96	12.21	22.90	12.31	22.85	12.41	22.79	12.51	26
27	23.84	12.68	23.78	12.78	23.73	12.88	23.67	12.99	27
28	24.72	13.15	24.66	13.25	24.61	13.36	24.55	13.47	28
29	25.61	13.61	25.55	13.73	25.49	13.84	25.43	13.95	29
30	26.49	14.08	26.43	14.20	26.36	14.31	26.30	14.43	30
31	27.37	14.55	27.31	14.67	27.24	14 79	27.18	14.91	31
32	28.25	15.02	28.19	15.15	28.12	15.27	28.06	15.39	32
33	29.14	15.49	29.07	15.62	29.00	15.75	28.93	15.87	33
34	30.02	15.96	29.95	16.09	29.88	16.22	29.81	16.35	34
35	30.90	16.43	30.83	16.57	30.76	16.70	30.69	16 83	35
36	31.79	16.90	31.71	17.04	31.64	17.18	31.56	17.32	36
37	32.67	17.37	32.59	17.51	32.52	17.65	32.44	17.80	37
38	33.55	17.84	33.47	17.99	33.39	18.13	33.32	18.28	38
39	34.43	18.31	34.35	18.46	34.27	18.61	34.19	18 76	39
40	35.32	18.78	35.24	18.93	35.15	19.09	35.07	19.24	40
41	36.20	19.25	36.12	19.41	36.08	19.56	35.95	19.72	41
42	37.08	19.72	37.00	19.88	36.91	20.04	36.82	20.20	42
43	37.97	20.19	37.88	20.35	37.79	20.52	37.70	20.68	43
44	38 85	20.66	38.76	20.83	38 67	20.99	38.58	21.16	44
45	39.73	21.13	39.64	21.30	39.55	21.47	39.45	21.64	45
46	40.62	21.60	40.52	21.77	40.43	21.95	40.33	22.13	46
47	41.50	22.07	41.40	22.25	41.30	22.43	41.21	22.61	47
48	42.38	22.53	42.28	22.72	42.18	22.90	42.08	23.09	48
49	43.26	23.00	43.16	23.19	43.06	23.38	42.96	23.57	49
50	44.15	23.47	44.04	23.67	43.94	23.86	43.84	24.05	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep	Lat	Distance.
	62 Deg.		61¾ Deg.		61½ Deg.		61¼ Deg.		

Distance.	28 Deg.		28¼ Deg.		28½ Deg.		28¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	45.03	23.94	44.93	24.14	44.82	24.34	44.71	24.53	51
52	45.91	24.41	45.81	24.61	45.70	24.81	45.59	25.01	52
53	46.80	24.88	46.69	25.09	46.58	25.29	46.47	25.49	53
54	47.68	25.35	47.57	25.56	47.46	25.77	47.34	25.97	54
55	48.56	25.82	48.45	26.03	48.33	26.24	48.22	26.45	55
56	49.45	26.29	49.33	26.51	49.21	26.72	49.10	26.94	56
57	50.33	26.76	50.21	26.98	50.09	27.20	49.97	27.42	57
58	51.21	27.23	51.09	27.45	50.97	27.68	50.85	27.90	58
59	52.09	27.70	51.97	27.93	51.85	28.15	51.73	28.38	59
60	52.98	28.17	52.85	28.40	52.73	28.63	52.60	28.86	60
61	53.86	28.64	53.73	28.87	53.61	29.11	53.48	29.34	61
62	54.74	29.11	54.62	29.35	54.49	29.58	54.36	29.82	62
63	55.63	29.58	55.50	29.82	55.37	30.06	55.23	30.30	63
64	56.51	30.05	56.38	30.29	56.24	30.54	56.11	30.78	64
65	57.39	30.52	57.26	30.77	57.12	31.02	56.99	31.26	65
66	58.27	30.99	58.14	31.24	58.00	31.49	57.86	31.75	66
67	59.16	31.45	59.02	31.71	58.88	31.97	58.74	32.23	67
68	60.04	31.92	59.90	32.19	59.76	32.45	59.62	32.71	68
69	60.92	32.39	60.78	32.66	60.64	32.92	60.49	33.19	69
70	61.81	32.86	61.66	33.13	61.52	33.40	61.37	33.67	70
71	62.69	33.33	62.54	33.61	62.40	33.88	62.25	34.15	71
72	63.57	33.80	63.42	34.08	63.27	34.36	63.12	34.63	72
73	64.46	34.27	64.30	34.55	64.15	34.83	64.00	35.11	73
74	65.34	34.74	65.19	35.03	65.03	35.31	64.88	35.59	74
75	66.22	35.21	66.07	35.50	65.91	35.79	65.75	36.07	75
76	67.10	35.68	66.95	35.97	66.79	36.26	66.63	36.56	76
77	67.99	36.15	67.83	36.45	67.67	36.74	67.51	37.04	77
78	68.87	36.62	68.71	36.92	68.55	37.22	68.38	37.52	78
79	69.75	37.09	69.59	37.39	69.43	37.70	69.26	38.00	79
80	70.64	37.56	70.47	37.87	70.31	38.17	70.14	38.48	80
81	71.52	38.03	71.35	38.34	71.18	38.65	71.01	38.96	81
82	72.40	38.50	72.23	38.81	72.06	39.13	71.89	39.44	82
83	73.28	38.97	73.11	39.29	72.94	39.60	72.77	39.92	83
84	74.17	39.44	73.99	39.76	73.82	40.08	73.64	40.40	84
85	75.05	39.91	74.88	40.23	74.70	40.56	74.52	40.88	85
86	75.93	40.37	75.76	40.71	75 58	41.04	75.40	41.36	86
87	76.82	40.84	76.64	41.18	76.46	41.51	76.28	41.85	87
88	77.70	41.31	77.52	41.65	77.34	41.99	77.15	42.33	88
89	78.58	41.78	78.40	42.13	78.21	42.47	78.03	42.81	89
90	79.47	42.25	79.28	42.60	79.09	42.94	78.91	43.29	90
91	80.35	42.72	80.16	43.07	79.97	43.42	79.78	43.77	91
92	81.23	43.19	81.04	43.55	80.85	43.90	80.66	44 25	92
93	82.11	43.66	81.92	44.02	81.73	44.38	81.54	44 73	93
94	83.00	44.13	82.80	44.49	82.61	44.85	82.41	45.21	94
95	83.88	44.60	83.68	44.97	83.49	45.33	83.29	45.69	95
96	84.76	45.07	84.57	45.44	84.37	45.81	84.17	46.17	96
97	85.65	45.54	85.45	45.91	85.25	46.28	85.04	46.66	97
98	86.53	46.01	86 33	46.39	86.12	46.76	85.92	47.14	98
99	87.41	46.48	87.21	46.86	87.00	47.24	86.80	47.62	99
100	88.29	46.95	88.09	47.33	87.88	47.72	87.67	48.10	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	62 Deg.		61¾ Deg.		61½ Deg.		61¼ Deg.		

Distance.	29 Deg.		29¼ Deg.		29½ Deg.		29¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.87	0 48	0.87	0.49	0.87	0.49	0.87	0.50	1
2	1.75	0.97	1.74	0.98	1.74	0.98	1.74	0.99	2
3	2.62	1.45	2.62	1.47	2.61	1.48	2.60	1.49	3
4	3.50	1.94	3.49	1.95	3.48	1.97	3.47	1.98	4
5	4 37	2.42	4. 36	2.44	4.35	2.46	4.34	2.48	5
6	5.25	2.91	5.23	2.93	5.22	2.95	5.21	2.98	6
7	6.12	3.39	6.11	3.42	6.09	3.45	6.08	3.47	7
8	7.00	3.88	6.98	3.91	6.96	3.94	6.95	3.97	8
9	7.87	4.36	7.85	4.40	7.83	4.43	7.81	4.47	9
10	8.75	4.85	8.72	4.89	8.70	4.92	8.68	4.96	10
11	9.62	5.33	9.60	5.37	9.57	5.42	9.55	5.46	11
12	10.50	5.82	10.47	5.86	10.44	5.91	10.42	5.95	12
13	11.37	6.30	11.34	6.35	11.31	6.40	11.29	6.45	13
14	12.24	6.79	12.21	6.84	12.18	6.89	12.15	6.95	14
15	13.12	7.27	13.09	7.33	13.06	7.39	13.02	7.44	15
16	13.99	7.76	13.96	7.82	13.93	7.88	13.89	7.94	16
17	14.87	8.24	14.83	8.31	14.80	8.37	14.76	8.44	17
18	15.74	8.73	15.70	8.80	15.67	8.86	15.63	8.93	18
19	16.62	9.21	16.58	9.28	16.54	9.36	16.50	9.43	19
20	17.49	9.70	17.45	9.77	17.41	9.85	17.36	9.92	20
21	18.37	10.18	18.32	10.26	18.28	10.34	18.23	10.42	21
22	19.24	10.67	19.19	10.75	19.15	10.83	19.10	10.92	22
23	20.12	11.15	20.07	11.24	20.02	11.33	19.97	11.41	23
24	20.99	11.64	20.94	11.73	20.89	11.82	20.84	11.91	24
25	21.87	12.12	21.81	12.22	21.76	12.31	21.70	12.41	25
26	22.74	12.60	22.68	12.70	22.63	12.80	22.57	12.90	26
27	23.61	13.09	23.56	13.19	23.50	13.30	23.44	13.40	27
28	24.49	13.57	24.43	13.68	24.37	13.79	24.31	13.89	28
29	25.36	14.06	25.30	14.17	25.24	14.28	25.18	14.39	29
30	26.24	14.54	26.17	14.66	26.11	14.77	26.05	14.89	30
31	27.11	15.03	27.05	15.15	26.98	15.27	26.91	15.38	31
32	27.99	15.51	27.92	15.64	27.85	15.76	27.78	15.88	32
33	28.86	16.00	28.79	16.12	28.72	16.25	28.65	16.38	33
34	29.74	16.48	29.66	16.61	29.59	16.74	29.52	16.87	34
35	30.61	16.97	30.54	17.10	30.46	17.23	30.39	17.37	35
36	31.49	17.45	31.41	17.59	31.33	17.73	31.26	17.86	36
37	32.36	17.94	32.28	18.08	32.20	18.22	32.12	18.36	37
38	33.24	18.42	33.15	18.57	33.07	18.71	32.99	18.86	38
39	34.11	18.91	34.03	19.06	33.94	19.20	33.86	19.35	39
40	34.98	19.39	34.90	19.54	34.81	19.70	34.73	19.85	40
41	35.86	19.88	35.77	20.03	35.68	20.19	35.60	20.34	41
42	36.73	20.36	36.64	20.52	36.55	20.68	36.46	20.84	42
43	37.61	20.85	37.52	21.01	37.43	21.17	37.33	21.34	43
44	38.48	21.33	38.39	21.50	38.30	21.67	38.20	21.83	44
45	39.36	21.82	39.26	21.99	39.17	22.16	39.07	22.33	45
46	40.23	22.30	40.13	22.48	40.04	22.65	39.94	22.83	46
47	41.11	22.79	41.01	22.97	40.91	23.14	40.81	23.32	47
48	41.98	23.27	41.88	23.45	41.78	23.68	41.67	23.82	48
49	42 86	23.76	42.75	23.94	42.65	24.13	42.54	24.31	49
50	43.73	24.24	43.62	24.43	43.52	24.62	43.41	24.81	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	61 Deg.		60¾ Deg.		60½ Deg.		60¼ Deg.		

Distance.	29 Deg.		29¼ Deg.		29½ Deg.		29¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	44.61	24.73	44.50	24.92	44.39	25.11	44.28	25.31	51
52	45.48	25.21	45.37	25.41	45.26	25.61	45.15	25.80	52
53	46.35	25.69	46.24	25.90	46.13	26.10	46.01	26.30	53
54	47.23	26.18	47.11	26.39	47.00	26.59	46.88	26.80	54
55	48.10	26.66	47.99	26.87	47.87	27.08	47.75	27.29	55
56	48.98	27.15	48.86	27.36	48.74	27.58	48.62	27.79	56
57	49.85	27.63	49.73	27.85	49.61	28.07	49.49	28.28	57
58	50.73	28.12	50.60	28.34	50.48	28.56	50.36	28.78	58
59	51.60	28.60	51.48	28.83	51.35	29.05	51.22	29.28	59
60	52.48	29.09	52.35	29.32	52.22	29.55	52.09	29.77	60
61	53.35	29.57	53.22	29.81	53.09	30.04	52.96	30.27	61
62	54.23	30.06	54.09	30.29	53.96	30.53	53.83	30.77	62
63	55.10	30.54	54.97	30.78	54.83	31.02	54.70	31.26	63
64	55.98	31.03	55.84	31.27	55.70	31.52	55.56	31.76	64
65	56.85	31.51	56.71	31.76	56.57	32.01	56.43	32.25	65
66	57.72	32.00	57.58	32.25	57.44	32.50	57.30	32.75	66
67	58.60	32.48	58.46	32.74	58.31	32.99	58.17	33.25	67
68	59.47	32.97	59.33	33.23	59.18	33.48	59.04	33.74	68
69	60.35	33.45	60.20	33.71	60.05	33.98	59.91	34.24	69
70	61.22	33.94	61.07	34.20	60.92	34.47	60.77	34.74	70
71	62.10	34.42	61.95	34.69	61.80	34.96	61.64	35.23	71
72	62.97	34.91	62.82	35.18	62.67	35.45	62.51	35.73	72
73	63.85	35.39	63.69	35.67	63.54	35.95	63.38	36.22	73
74	64.72	35.88	64.56	36.16	64.41	36.44	64.25	36.72	74
75	65.60	36.36	65.44	36.65	65.28	36.93	65.11	37.22	75
76	66.47	36.85	66.31	37.14	66.15	37.42	65.98	37.71	76
77	67.35	37.33	67.18	37.62	67.02	37.92	66.85	38.21	77
78	68.22	37.82	68.05	38.11	67.89	38.41	67.72	38.70	78
79	69.09	38.30	68.93	38.60	68.76	38.90	68.59	39.20	79
80	69.97	38.78	69.80	39.09	69.63	39.39	69.46	39.70	80
81	70.84	39.27	70.67	39.58	70.50	39.89	70.32	40.19	81
82	71.72	39.75	71.54	40.07	71.37	40.38	71.19	40.69	82
83	72.59	40.24	72.42	40.56	72.24	40.87	72.06	41.19	83
84	73.47	40.72	73.29	41.04	73.11	41.36	72.93	41.68	84
85	74.34	41.21	74.16	41.53	73.98	41.86	73.80	42.18	85
86	75.22	41.69	75.03	42.02	74.85	42.35	74.67	42.67	86
87	76.09	42.18	75.91	42.51	75.72	42.84	75.53	43.17	87
88	76.97	42.65	76.78	43.00	76.59	43.33	76.40	43.67	88
89	77.84	43.15	77.65	43.49	77.46	43.83	77.27	44.16	89
90	78.72	43.63	78.52	43.98	78.33	44.32	78.14	44.66	90
91	79.59	44.12	79.40	44.46	79.20	44.81	79.01	45.16	91
92	80.46	44.60	80.27	44.95	80.07	45.30	79.87	45.65	92
93	81.34	45.09	81.14	45.44	80.94	45.80	80.74	46.15	93
94	82.21	45.57	82.01	45.93	81.81	46.29	81.61	46.64	94
95	83.09	46.06	82.89	46.42	82.68	46.78	82.48	47.14	95
96	83.96	46.54	83.76	46.91	83.55	47.27	83.35	47.64	96
97	84.84	47.03	84.63	47.40	84.42	47.77	84.22	48.13	97
98	85.71	47.51	85.50	47.88	85.29	48.26	85.08	48.63	98
99	86.59	48.00	86.38	48.37	86.17	48.75	85.95	49.13	99
100	87.46	48.48	87.25	48.86	87.04	49.24	86.82	49.62	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	61 Deg.		60¾ Deg.		60½ Deg.		60¼ Deg.		

Distance.	30 Deg.		30¼ Deg.		30½ Deg.		30¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.87	0.50	0.86	0.50	0.86	0.51	0.86	0.51	1
2	1.73	1.00	1.73	1.01	1.72	1.02	1.72	1.02	2
3	2.60	1.50	2.59	1.51	2.58	1.52	2.58	1.53	3
4	3.46	2.00	3.46	2.02	3.45	2.03	3.44	2.05	4
5	4.33	2.50	4.32	2.52	4.31	2.54	4.30	2.56	5
6	5.20	3.00	5.18	3.02	5.17	3.05	5.16	3.07	6
7	6.06	3.50	6.05	3.53	6.03	3.55	6.02	3.58	7
8	6.93	4.00	6.91	4.03	6.89	4.06	6.88	4.09	8
9	7.79	4.50	7.77	4.53	7.75	4.57	7.73	4.60	9
10	8.66	5.00	8.64	5.04	8.62	5.08	8.59	5.11	10
11	9.53	5.50	9.50	5.54	9.48	5.58	9.45	5.62	11
12	10.39	6.00	10.37	6.05	10.34	6.09	10.31	6.14	12
13	11.26	6.50	11.23	6.55	11.20	6.60	11.17	6.65	13
14	12.12	7.00	12.09	7.05	12.06	7.11	12.03	7.16	14
15	12.99	7.50	12.96	7.56	12.92	7.61	12.89	7.67	15
16	13.86	8.00	13.82	8.06	13.79	8.12	13.75	8.18	16
17	14.72	8.50	14.69	8.56	14.65	8.63	14.61	8.69	17
18	15.59	9.00	15.55	9.07	15.51	9.14	15.47	9.20	18
19	16.45	9.50	16.41	9.57	16.37	9.64	16.33	9.71	19
20	17.32	10.00	17.28	10.08	17.23	10.15	17.19	10.23	20
21	18.19	10.50	18.14	10.58	18.09	10.66	18.05	10.74	21
22	19.05	11.00	19.00	11.08	18.96	11.17	18.91	11.25	22
23	19.92	11.50	19.87	11.59	19.82	11.67	19.77	11.76	23
24	20.78	12.00	20.73	12.09	20.68	12.18	20.63	12.27	24
25	21.65	12.50	21.60	12.59	21.54	12.69	21.49	12.78	25
26	22.52	13.00	22.46	13.10	22.40	13.20	22.34	13.29	26
27	23.38	13.50	23.32	13.60	23.26	13.70	23.20	13.80	27
28	24.25	14.00	24.19	14.11	24.13	14.21	24.06	14.32	28
29	25.11	14.50	25.05	14.61	24.99	14.72	24.92	14.83	29
30	25.98	15.00	25.92	15.11	25.85	15.23	25.78	15.34	30
31	26.85	15.50	26.78	15.62	26.71	15.73	26.64	15.85	31
32	27.71	16.00	27.64	16.12	27.57	16.24	27.50	16.36	32
33	28.58	16.50	28.51	16.62	28.43	16.75	28.36	16.87	33
34	29.44	17.00	29.37	17.13	29.30	17.26	29.22	17.38	34
35	30.31	17.50	30.23	17.63	30.16	17.76	30.08	17.90	35
36	31.18	18.00	31.10	18.14	31.02	18.27	30.94	18.41	36
37	32.04	18.50	31.96	18.64	31.88	18.78	31.80	18.92	37
38	32.91	19.00	32.83	19.14	32.74	19.29	32.66	19.43	38
39	33.77	19.50	33.69	19.65	33.60	19.79	33.52	19.94	39
40	34.64	20.00	34.55	20.15	34.47	20.30	34.38	20.45	40
41	35.51	20.50	35.42	20.65	35.33	20.81	35.24	20.96	41
42	36.37	21.00	36.28	21.16	36.19	21.32	36.10	21.47	42
43	37.24	21.50	37.14	21.66	37.05	21.82	36.95	21.99	43
44	38.11	22.00	38.01	22.17	37.91	22.33	37.81	22.50	44
45	38.97	22.50	38.87	22.67	38.77	22.84	38.67	23.01	45
46	39.84	23.00	39.74	23.17	39.63	23.35	39.53	23.52	46
47	40.70	23.50	40.60	23.68	40.50	23.85	40.39	24.03	47
48	41.57	24.00	41.46	24.18	41.36	24.36	41.25	24.54	48
49	42.44	24.50	42.33	24.68	42.22	24.87	42.11	25.05	49
50	43.30	25.00	43.19	25.19	43.08	25.38	42.97	25.56	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	60 Deg.		59¾ Deg.		59½ Deg.		59¼ Deg.		

Distance.	30 Deg.		30¼ Deg.		30½ Deg.		30¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	44.17	25.50	44.06	25.69	43.94	25.88	43.83	26.08	51
52	45.03	26.00	44.92	26.20	44.80	26.39	44.69	26.59	52
53	45.90	26.50	45.78	26.70	45.67	26.90	45.55	27.10	53
54	46.77	27.00	46.65	27.20	46.53	27.41	46.41	27.61	54
55	47.63	27.50	47.51	27.71	47.39	27.91	47.27	28.12	55
56	48.50	28.00	48.37	28.21	48.25	28.42	48.13	28.63	56
57	49.36	28.50	49.24	28.72	49.11	28.93	48.99	29.14	57
58	50.23	29.00	50.10	29.22	49.97	29.44	49.85	29.65	58
59	51.10	29.50	50.97	29.72	50.84	29.94	50.70	30.17	59
60	51.96	30.00	51.83	30.23	51.70	30.45	51.56	30.68	60
61	52.83	30.50	52.69	30.73	52.56	30.96	52.42	31.19	61
62	53.69	31.00	53.56	31.23	53.42	31.47	53.28	31.70	62
63	54.56	31.50	54.42	31.74	54.28	31.97	54.14	32.21	63
64	55.43	32.00	55.29	32.24	55.14	32.48	55.00	32.72	64
65	56.29	32.50	56.15	32.75	56.01	32.99	55.86	33.23	65
66	57.16	33.00	57.01	33.25	56.87	33.50	56.72	33.75	66
67	58.02	33.50	57.88	33.75	57.73	34.01	57.58	34.26	67
68	58.89	34.00	58.74	34.26	58.59	34.51	58.44	34.77	68
69	59.76	34.50	59.60	34.76	59.45	35.02	59.30	35.28	69
70	60.62	35.00	60.47	35.26	60.31	35.53	60.16	35.79	70
71	61.49	35.50	61.33	35.77	61.18	36.04	61.02	36.30	71
72	62.35	36.00	62.20	36.27	62.04	36.54	61.88	36.81	72
73	63.22	36.50	63.06	36.78	62.90	37.05	62.74	37.32	73
74	64.09	37.00	63.92	37.28	63.76	37.56	63.60	37.84	74
75	64.95	37.50	64.79	37.78	64.62	38.07	64.46	38.35	75
76	65.82	38.00	65.65	38.29	65.48	38.57	65.31	38.86	76
77	66.68	38.50	66.52	38.79	66.35	39.08	66.17	39.37	77
78	67.55	39.00	67.38	39.29	67.21	39.59	67.03	39.88	78
79	68.42	39.50	68.24	39.80	68.07	40.10	67.89	40.39	79
80	69.28	40.00	69.11	40.30	68.93	40.60	68.75	40.90	80
81	70.15	40.50	69.97	40.81	69.79	41.11	69.61	41.41	81
82	71.01	41.00	70.83	41.31	70.65	41.62	70.47	41.93	82
83	71.88	41.50	71.70	41.81	71.52	42.13	71.33	42.44	83
84	72.75	42.00	72.56	42.32	72.38	42.63	72.19	42.95	84
85	73.61	42.50	73.43	42.82	73.24	43.14	73.05	43.46	85
86	74.48	43.00	74.29	43.32	74.10	43.65	73.91	43.97	86
87	75.34	43.50	75.15	43.83	74.96	44.16	74.77	44.48	87
88	76.21	44.00	76.02	44.33	75.82	44.66	75.63	44.99	88
89	77.08	44.50	76.88	44.84	76.68	45.17	76.49	45.51	89
90	77.94	45.00	77.75	45.34	77.55	45.68	77.35	46.02	90
91	78.81	45.50	78.61	45.84	78.41	46.19	78.21	46.53	91
92	79.67	46.00	79.47	46.35	79.27	46.69	79.07	47.04	92
93	80.54	46.50	80.34	46.85	80.13	47.20	79.92	47.55	93
94	81.41	47.00	81.20	47.35	80.99	47.71	80.78	48.06	94
95	82.27	47.50	82.06	47.86	81.85	48.22	81.64	48.57	95
96	83.14	48.00	82.93	48.36	82.72	48.72	82.50	49.08	96
97	84.00	48.50	83.79	48.87	83.58	49.23	83.36	49.60	97
98	84.87	49.00	84.66	49.37	84.44	49.74	84.22	50.11	98
99	85.74	49.50	85.52	49.87	85.30	50.25	85.08	50.62	99
100	86.60	50.00	86.38	50.38	86.16	50.75	85.94	51.13	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	60 Deg.		59¾ Deg.		59½ Deg.		59¼ Deg.		

Distance.	31 Deg.		31¼ Deg.		31½ Deg.		31¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.86	0.51	0.85	0.52	0.85	0.52	0.85	0.53	1
2	1.71	1.03	1.71	1.04	1.71	1.04	1.70	1.05	2
3	2.57	1.55	2.56	1.56	2.56	1.57	2.55	1.58	3
4	3.43	2.06	3.42	2.08	3.41	2.09	3.40	2.10	4
5	4.29	2.58	4.27	2.59	4.26	2.61	4.25	2.63	5
6	5.14	3.09	5.13	3.11	5.12	3.13	5.10	3.16	6
7	6.00	3.61	5.98	3.63	5.97	3.66	5.95	3.68	7
8	6.86	4.12	6.84	4.15	6.82	4.18	6.80	4.21	8
9	7.71	4.64	7.69	4.67	7.67	4.70	7.65	4.74	9
10	8.57	5.15	8.55	5.19	8.53	5.22	8.50	5.26	10
11	9.43	5.67	9.40	5.71	9.38	5.75	9.35	5.79	11
12	10.29	6.18	10.26	6.23	10.23	6.27	10.20	6.31	12
13	11.14	6.70	11.11	6.74	11.08	6.79	11.05	6.84	13
14	12.00	7.21	11.97	7.26	11.94	7.31	11.90	7.37	14
15	12.86	7.73	12.82	7.78	12.79	7.84	12.76	7.89	15
16	13.71	8.24	13.68	8.30	13.64	8.36	13.61	8.42	16
17	14.57	8.76	14.53	8.82	14.49	8.88	14.46	8.95	17
18	15.43	9.27	15.39	9.34	15.35	9.40	15.31	9.47	18
19	16.29	9.79	16.24	9.86	16.20	9.93	16.16	10.00	19
20	17.14	10.30	17.10	10.38	17.05	10.45	17.01	10.52	20
21	18.00	10.82	17.95	10.89	17.91	10.97	17.86	11.05	21
22	18.86	11.33	18.81	11.41	18.76	11.49	18.71	11.58	22
23	19.71	11.85	19.66	11.93	19.61	12.02	19.56	12.10	23
24	20.57	12.36	20.52	12.45	20.46	12.54	20.41	12.63	24
25	21.43	12.88	21.37	12.97	21.32	13.06	21.26	13.16	25
26	22.29	13.39	22.23	13.49	22.17	13.58	22.11	13.68	26
27	23.14	13.91	23.08	14.01	23.02	14.11	22.96	14.21	27
28	24.00	14.42	23.94	14.53	23.87	14.63	23.81	14.73	28
29	24.86	14.94	24.79	15.04	24.73	15.15	24.66	15.26	29
30	25.71	15.45	25.65	15.56	25.58	15.67	25.51	15.79	30
31	26.57	15.97	26.50	16.08	26.43	16.20	26.36	16.31	31
32	27.43	16.48	27.36	16.60	27.28	16.72	27.21	16.84	32
33	28.29	17.00	28.21	17.12	28.14	17.24	28.06	17.37	33
34	29.14	17.51	29.07	17.64	28.99	17.76	28.91	17.89	34
35	30.00	18.03	29.92	18.16	29.84	18.29	29.76	18.42	35
36	30.86	18.54	30.78	18.68	30.70	18.81	30.61	18.94	36
37	31.72	19.06	31.63	19.19	31.55	19.33	31.46	19.47	37
38	32.57	19.57	32.49	19.71	32.40	19.85	32.31	20.00	38
39	33.43	20.09	33.34	20.23	33.25	20.38	33.16	20.52	39
40	34.29	20.60	34.20	20.75	34.11	20.90	34.01	21.05	40
41	35.14	21.12	35.05	21.27	34.96	21.42	34.86	21.57	41
42	36.00	21.63	35.91	21.79	35.81	21.94	35.71	22.10	42
43	36.86	22.15	36.76	22.31	36.66	22.47	36.57	22.63	43
44	37.72	22.66	37.62	22.83	37.52	22.99	37.42	23.15	44
45	38.57	23.18	38.47	23.34	38.37	23.51	38.27	23.68	45
46	39.43	23.69	39.33	23.86	39.22	24.03	39.12	24.21	46
47	40.29	24.21	40.18	24.38	40.07	24.56	39.97	24.73	47
48	41.14	24.72	41.04	24.90	40.93	25.08	40.82	25.26	48
49	42.00	25.24	41.89	25.42	41.78	25.60	41.67	25.78	49
50	42.86	25.75	42.75	25.94	42.63	26.12	42.52	26.31	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	59 Deg.		58¾ Deg.		58½ Deg.		58¼ Deg.		

Distance.	31 Deg.		31¼ Deg.		31½ Deg.		31¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	43.72	26.27	43.60	26.46	43.48	26.65	43.37	26.84	51
52	44.57	26.78	44.46	26.98	44.34	27.17	44.22	27.36	52
53	45.43	27.30	45.31	27.49	45.19	27.69	45.07	27.89	53
54	46.29	27.81	46.17	28.01	46.04	28.21	45.92	28.42	54
55	47.14	28.33	47.02	28.53	46.90	28.74	46.77	28.94	55
56	48.00	28.84	47.88	29.05	47.75	29.26	47.62	29.47	56
57	48.86	29.36	48.73	29.57	48.60	29.78	48.47	29.99	57
58	49.72	29.87	49.58	30.09	49.45	30.30	49.32	30.52	58
59	50.57	30.39	50.44	30.61	50.31	30.83	50.17	31.05	59
60	51.43	30.90	51.29	31.13	51.16	31.35	51.02	31.57	60
61	52.29	31.42	52.15	31.65	52.01	31.87	51.87	32.10	61
62	53.14	31.93	53.00	32.16	52.86	32.39	52.72	32.63	62
63	54.00	32.45	53.86	32.68	53.72	32.92	53.57	33.15	63
64	54.86	32.96	54.71	33.20	54.57	33.44	54.42	33.68	64
65	55.72	33.48	55.57	33.72	55.42	33.96	55.27	34.20	65
66	56.57	33.99	56.42	34.24	56.27	34.48	56.12	34.73	66
67	57.43	34.51	57.28	34.76	57.13	35.01	56.98	35.26	67
68	58.29	35.02	58.13	35.28	57.98	35.53	57.82	35.78	68
69	59.14	35.54	58.99	35.80	58.83	36.05	58.67	36.31	69
70	60.00	36.05	59.84	36.31	59.68	36.57	59.52	36.83	70
71	60.86	36.57	60.70	36.83	60.54	37.10	60.37	37.36	71
72	61.72	37.08	61.55	37.35	61.39	37.62	61.23	37.89	72
73	62.57	37.60	62.41	37.87	62.24	38.14	62.08	38.41	73
74	63.43	38.11	63.26	38.39	63.10	38.66	62.93	38.94	74
75	64.29	38.63	64.12	38.91	63.95	39.19	63.78	39.47	75
76	65.14	39.14	64.97	39.43	64.80	39.71	64.63	39.99	76
77	66.00	39.66	65.83	39.95	65.65	40.23	65.48	40.52	77
78	66.86	40.17	66.68	40.46	66.51	40.75	66.33	41.04	78
79	67.72	40.69	67.54	40.98	67.36	41.28	67.18	41.57	79
80	68.57	41.20	68.39	41.50	68.21	41.80	68.03	42.10	80
81	69.43	41.72	69.25	42.02	69.06	42.32	68.88	42.62	81
82	70.29	42.23	70.10	42.54	69.92	42.84	69.73	43.15	82
83	71.14	42.75	70.96	43.06	70.77	43.37	70.58	43.68	83
84	72.00	43.26	71.81	43.58	71.62	43.89	71.43	44.20	84
85	72.86	43.78	72.67	44.10	72.47	44.41	72.28	44.73	85
86	73.72	44.29	73.52	44.61	73.33	44.93	73.13	45.25	86
87	74.57	44.81	74.38	45.13	74.18	45.46	73.98	45.78	87
88	75.43	45.32	75.23	45.65	75.03	45.98	74.83	46.31	88
89	76.29	45.84	76.09	46.17	75.88	46.50	75.68	46.83	89
90	77.15	46.35	76.94	46.69	76.74	47.02	76.53	47.36	90
91	78.00	46.87	77.80	47.21	77.59	47.55	77.38	47.89	91
92	78.86	47.38	78.65	47.73	78.44	48.07	78.23	48.41	92
93	79.72	47.90	79.51	48.25	79.30	48.59	79.08	48.94	93
94	80.57	48.41	80.36	48.76	80.15	49.11	79.93	49.47	94
95	81.43	48.93	81.22	49.28	81.00	49.64	80.78	49.99	95
96	82.29	49.44	82.07	49.80	81.85	50.16	81.63	50.52	96
97	83.15	49.96	82.93	50.32	82.71	50.68	82.48	51.04	97
98	84.00	50.47	83.78	50.84	83.56	51.20	83.33	51.57	98
99	84.86	50.99	84.64	51.36	84.41	51.73	84.18	52.10	99
100	85.72	51.50	85.49	51.88	85.26	52.25	85.04	52.62	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	istance.
	59 Deg.		58¾ Deg.		58½ Deg.		58¼ Deg.		

Distance	32 Deg.		32¼ Deg.		32½ Deg.		32¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0 85	0.53	0.85	0.53	0.84	0.54	0 84	0.54	1
2	1.70	1.06	1.69	1.07	1.69	1.07	1.68	1 08	2
3	2.54	1.59	2.54	1.60	2.53	1.61	2.52	1.62	3
4	3.39	2.12	3.38	2.13	3.37	2.15	3.36	2.16	4
5	4.24	2.65	4.23	2.67	4.22	2.69	4.21	2.70	5
6	5.09	3.18	5.07	3.20	5.06	3.22	5.05	3.25	6
7	5.94	3.71	5.92	3.74	5.90	3.76	5.89	3.79	7
8	6.78	4.24	6.77	4.27	6.75	4.30	6.73	4.33	8
9	7.63	4.77	7.61	4.80	7.59	4.84	7.57	4.87	9
10	8.48	5.30	8.46	5.34	8.43	5.37	8.41	5.41	10
11	9.33	5.83	9.30	5.87	9.28	5.91	9.25	5.95	11
12	10.18	6.36	10.15	6.40	10.12	6.45	10.09	6.49	12
13	11.02	6.89	10.99	6.94	10.96	5.98	10.93	7.03	13
14	11.87	7.42	11.84	7.47	11.81	7.52	11.77	7.57	14
15	12.72	7.95	12.69	8.00	12.65	8.06	12.62	8.11	15
16	13.57	8.48	13.53	8.54	13.49	8.60	13.46	8.66	16
17	14.42	9.01	14.38	9.07	14.34	9.13	14.30	9.20	17
18	15.26	9.54	15.22	9.61	15.18	9.67	15.14	9.74	18
19	16.11	10.07	16.07	10.14	16.02	10.21	15.98	10.28	19
20	16.96	10.60	16.91	10.67	16.87	10.75	16.82	10.82	20
21	17.81	11.13	17.76	11.21	17.71	11.28	17.66	11.36	21
22	18.66	11.66	18.61	11.74	18.55	11.82	18.50	11.90	22
23	19.51	12.19	19.45	12.27	19.40	12.36	19.34	12.44	23
24	20.35	12.72	20.30	12.81	20.24	12.90	20.18	12.98	21
25	21.20	13.25	21.14	13.34	21.08	13.43	21.03	13.52	25
26	22.05	13.78	21.99	13.87	21.93	13.97	21.87	14.07	26
27	22.90	14.31	22.83	14.41	22.77	14.51	22.71	14.61	27
28	23.75	14.84	23.68	14.94	23.61	15.04	23.55	15.15	28
29	24.59	15.37	24.53	15.47	24.46	15.58	24.39	15.69	29
30	25.44	15.90	25.37	16.01	25.30	16.12	25.23	16.23	30
31	26.29	16.43	26.22	16.54	26.15	16.66	26.07	16.77	31
32	27.14	16.96	27.06	17.08	26.99	17.19	26.91	17.31	32
33	27.99	17.49	27.91	17.61	27.83	17.73	27.75	17.85	33
34	28.83	18.02	28.75	18.14	28.68	18.27	28.60	18.39	34
35	29.68	18.55	29.60	18.68	29.52	18.81	29.44	18.93	35
36	30.53	19.08	30.45	19.21	30.36	19.34	30.28	19.48	36
37	31.38	19.61	31.29	19.74	31.21	19.88	31.12	20.02	37
38	32.23	20.14	32.14	20.28	32.05	20.42	31.96	20.56	38
39	33.07	20.67	32.98	20.81	32.89	20.95	32.80	21.10	39
40	33.92	21.20	33.83	21.34	33.74	21.49	33.64	21.64	40
41	34.77	21.73	34.67	21.88	34.58	22.03	34.48	22.18	41
42	35.62	22.26	35.52	22.41	35.42	22.57	35.32	22.72	42
43	36.47	22.79	36.37	22.95	36.27	23.10	36.16	23.26	43
44	37.31	23.32	37.21	23.48	37.11	23.64	37.01	23.80	44
45	38 16	23.85	38.06	24.01	37.95	24.18	37.85	24.34	45
46	39.01	24.38	38.90	24.55	38.80	24.72	38.69	24.88	46
4	39.86	24.91	39.75	25.08	39.64	25.25	39.53	25.43	47
48	40.71	25.44	40.59	25.61	40.48	25.79	40.37	25.97	48
49	41.55	25.97	41.44	26.15	41.33	26.33	41.21	26.51	49
50	42.40	26.50	42.29	26.68	42.17	26.86	42.05	27.05	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat	Dep.	Lat.	Distance.
	58 Deg.		57¾ Deg.		57½ Deg.		57¼ Deg.		

Distance.	32 Deg.		32¼ Deg.		32½ Deg.		32¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	43.25	27.03	43.13	27.21	43.01	27.40	42.89	27.59	51
52	44.10	27.56	43.98	27.75	43.86	27.94	43.73	28.13	52
53	44.95	28.09	44.82	28.28	44.70	28.48	44.58	28.67	53
54	45.79	28.62	45.67	28.82	45.54	29.01	45.42	29.21	54
55	46.64	29.15	46.51	29.35	46.39	29.55	46.26	29.75	55
56	47.49	29.68	47.36	29.88	47.23	30.09	47.10	30.29	56
57	48.34	30.21	48.21	30.42	48.07	30.63	47.94	30.84	57
58	49.19	30.74	49.05	30.95	48.92	31.16	48.78	31.38	58
59	50.03	31.27	49.90	31.48	49.76	31.70	49.62	31.92	59
60	50.88	31.80	50.74	32.02	50.60	32.24	50.46	32.46	60
61	51.73	32.33	51.59	32.55	51.45	32.78	51.30	33.00	61
62	52.58	32.85	52.44	33.08	52.29	33.31	52.14	33.54	62
63	53.43	33.38	53.28	33.62	53.13	33.85	52.99	34.08	63
64	54.28	33.91	54.13	34.15	53.98	34.39	53.83	34.62	64
65	55.12	34.44	54.97	34.68	54.82	34.92	54.67	35.16	65
66	55.97	34.97	55.82	35.22	55.66	35.46	55.51	35.70	66
67	56.82	35.50	56.66	35.75	56.51	36.00	56.35	36.25	67
68	57.67	36.03	57.51	36.29	57.35	36.54	57.19	36.79	68
69	58.52	36.56	58.36	36.82	58.19	37.07	58.03	37.33	69
70	59.36	37.09	59.20	37.35	59.04	37.61	58.87	37.87	70
71	60.21	37.62	60.05	37.89	59.88	38.15	59.71	38.41	71
72	61.06	38.15	60.89	38.42	60.72	38.69	60.55	38.95	72
73	61.91	38.68	61.74	38.95	61.57	39.22	61.40	39.49	73
74	62.76	39.21	62.58	39.49	62.41	39.76	62.24	40.03	74
75	63.60	39.74	63.43	40.02	63.25	40.30	63.08	40.57	75
76	64.45	40.27	64.28	40.55	64.10	40.83	63.92	41.11	76
77	65.30	40.80	65.12	41.09	64.94	41.37	64.76	41.65	77
78	66.15	41.33	65.97	41.62	65.78	41.91	65.60	42.20	78
79	67.00	41.86	66.81	42.16	66.63	42.45	66.44	42.74	79
80	67.84	42.39	67.66	42.69	67.47	42.98	67.28	43.28	80
81	68.69	42.92	68.50	43.22	68.31	43.52	68.12	43.82	81
82	69.54	43.45	69.35	43.76	69.16	44.06	68.97	44.36	82
83	70.39	43.98	70.20	44.29	70.00	44.60	69.81	44.90	83
84	71.24	44.51	71.04	44.82	70.84	45.13	70.65	45.44	84
85	72.08	45.04	71.89	45.36	71.69	45.67	71.49	45.98	85
86	72.93	45.57	72.73	45.89	72.53	46.21	72.33	46.52	86
87	73.78	46.10	73.58	46.42	73.38	46.75	73.17	47.06	87
88	74.63	46.63	74.42	46.96	74.22	47.28	74.01	47.61	88
89	75.48	47.16	75.27	47.49	75.06	47.82	74.85	48.15	89
90	76.32	47.69	76.12	48.03	75.91	48.36	75.69	48.69	90
91	77.17	48.22	76.96	48.56	76.75	48.89	76.53	49.23	91
92	78.02	48.75	77.81	49.09	77.59	49.43	77.38	49.77	92
93	78.87	49.28	78.65	49.63	78.44	49.97	78.22	50.31	93
94	79.72	49.81	79.50	50.16	79.28	50.51	79.06	50.85	94
95	80.56	50.34	80.34	50.69	80.12	51.04	79.90	51.39	95
96	81.41	50.87	81.19	51.23	80.97	51.58	80.74	51.93	96
97	82.26	51.40	82.04	51.76	81.81	52.12	81.58	52.47	97
98	83.11	51.93	82.88	52.29	82.65	52.66	82.42	53.02	98
99	83.96	52.46	83.73	52.83	83.50	53.19	83.26	53.56	99
100	84.80	52.99	84.57	53.36	84.34	53.73	84.10	54.10	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	58 Deg.		57¾ Deg.		57½ Deg.		57¼ Deg.		

Distance.	33 Deg.		33¼ Deg.		33½ Deg		33¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.84	0.54	0.84	0.55	0.83	0.55	0.83	0.56	1
2	1.68	1.09	1.67	1.10	1.67	1.10	1.66	1.11	2
3	2.52	1.63	2.51	1.64	2.50	1.66	2.49	1.67	3
4	3.35	2.18	3.35	2.19	3.34	2.21	3.33	2.22	4
5	4.19	2.72	4.18	2.74	4.17	2.76	4.15	2.78	5
6	5.03	3.27	5.02	3.29	5.00	3.31	4.99	3.33	6
7	5.87	3.81	5.85	3.84	5.84	3.86	5.82	3.89	7
8	3.71	4.36	6.69	4.39	6.67	4.42	6.65	4.44	8
9	7.55	4.90	7.53	4.93	7.50	4.97	7.48	5.00	9
10	8.39	5.45	8.36	5.48	8.34	5.52	8.31	5.56	10
11	9.23	5.99	9.20	6.03	9.17	6.07	9.15	6.11	11
12	10.06	6.54	10.04	6.58	10.01	6.62	9.98	6.67	12
13	10.90	7.08	10.87	7.13	10.84	7.18	10.81	7.22	13
14	11.74	7.62	11.71	7.68	11.67	7.73	11.64	7.78	14
15	12.58	8.17	12.54	8.22	12.51	8.28	12.47	8.33	15
16	13.42	8.71	13.38	8.77	13.34	8.83	13.30	8.89	16
17	14.26	9.26	14.22	9.32	14.18	9.38	14.13	9.44	17
18	15.10	9.80	15.05	9.87	15.01	9.93	14.97	10.00	18
19	15.93	10.35	15.89	10.42	15.84	10.49	15.80	10.56	19
20	16.77	10.89	16.73	10.97	16.68	11.04	16.63	11.11	20
21	17.61	11.44	17.56	11.51	17.51	11.59	17.46	11.67	21
22	18.45	11.98	18.40	12.06	18.35	12.14	18.29	12.22	22
23	19.29	12.53	19.23	12.61	19.18	12.69	19.12	12.78	23
24	20.13	13.07	20.07	13.16	20.01	13.25	19.96	13.33	24
25	20.97	13.62	20.91	13.71	20.85	13.80	20.79	13.89	25
26	21.81	14.16	21.74	14.26	21.68	14.35	21.62	14.44	26
27	22.64	14.71	22.58	14.80	22.51	14.90	22.45	15.00	27
28	23.48	15.25	23.42	15.35	23.35	15.45	23.28	15.56	28
29	24.32	15.79	24.25	15.90	24.18	16.01	24.11	16.11	29
30	25.16	16.34	25.09	16.45	25.02	16.56	24.94	16.67	30
31	26.00	16.88	25.92	17.00	25.85	17.11	25.78	17.22	31
32	26.84	17.43	26.76	17.55	26.68	17.66	26.61	17.78	32
33	27.68	17.97	27.60	18.09	27.52	18.21	27.44	18.33	33
34	28.51	18.52	28.43	18.64	28.35	18.77	28.27	18.89	34
35	29.35	19.06	29.27	19.19	29.19	19.32	29.10	19.44	35
36	30.19	19.61	30.11	19.74	30.02	19.87	29.93	20.00	36
37	31.03	20.15	30.94	20.29	30.85	20.42	30.76	20.56	37
38	31.87	20.70	31.78	20.84	31.69	20.97	31.60	21.11	38
39	32.71	21.24	32.62	21.38	32.52	21.53	32.43	21.67	39
40	33.55	21.79	33.45	21.93	33.36	22.68	33.26	22.22	40
41	34.39	22.33	34.29	22.48	34.19	22.63	34.09	22.78	41
42	35.22	22.87	35.12	23.03	35.02	23.18	34.92	23.33	42
43	36.06	23.42	35.96	23.58	35.86	23.73	35.75	23.89	43
44	36.90	23.96	36.80	24.12	36.69	24.29	36.58	24.45	44
45	37.74	24.51	37.63	24.67	37.52	24.84	37.42	25.00	45
46	38.58	25.05	38.47	25.22	38.36	25.39	38.25	25.56	46
47	39.42	25.60	39.31	25.77	39.19	25.94	39.08	26.11	47
48	40.26	26.14	40.14	26.32	40.03	25.49	39.91	26.67	48
49	41.09	26.69	40.98	26.87	40.86	27.04	40.74	27.22	49
50	41.93	27.23	41.81	27.41	41.69	27.60	41.57	27.78	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	57 Deg.		56¾ Deg.		56½ Deg.		56¼ Deg.		

Distance.	33 Deg.		33¼ Deg.		33½ Deg.		33¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	42.77	27.78	42.65	27.96	42.53	28.15	42.40	28.33	51
52	43.61	28.32	43.49	28.51	43.36	28.70	43.24	28.89	52
53	44.45	28.87	44.32	29.06	44.20	29.25	44.07	29.45	53
54	45.29	29.41	45.16	29.61	45.03	29.80	44.90	30.00	54
55	46.13	29.96	46.00	30.16	45.86	30.36	45.73	30.56	55
56	46.97	30.50	46.83	30.70	46.70	30.91	46.56	31.11	56
57	47.80	31.04	47.67	31.25	47.53	31.46	47.39	31.67	57
58	48.64	31.59	48.50	31.80	48.37	32.01	48.23	32.22	58
59	49.48	32.13	49.34	32.35	49.20	32.56	49.06	32.78	59
60	50.32	32.68	50.18	32.90	50.03	33.12	49.89	33.33	60
61	51.16	33.22	51.01	33.45	50.87	33.67	50.72	33.89	61
62	52.00	33.77	51.85	33.99	51.70	34.22	51.55	34.45	62
63	52.84	34.31	52.69	34.54	52.53	34.77	52.38	35.00	63
64	53.67	34.86	53.52	35.09	53.37	35.32	53.21	35.56	64
65	54.51	35.40	54.36	35.64	54.20	35.88	54.05	36.11	65
66	55.35	35.95	55.19	36.19	55.04	36.43	54.88	36.67	66
67	56.19	36.49	56.03	36.74	55.87	36.98	55.71	37.22	67
68	57.03	37.04	56.87	37.28	56.70	37.53	56.54	37.78	68
69	57.87	37.58	57.70	37.83	57.54	38.08	57.37	38.33	69
70	58.71	38.12	58.54	38.38	58.37	38.64	58.20	38.89	70
71	59.55	38.67	59.38	38.93	59.21	39.19	59.03	39.45	71
72	60.38	39.21	60.21	39.48	60.04	39.74	59.87	40.00	72
73	61.22	39.76	61.05	40.03	60.87	40.29	60.70	40.56	73
74	62.06	40.30	61.89	40.57	61.71	40.84	61.53	41.11	74
75	62.90	40.85	62.72	41.12	62.54	41.40	62.36	41.67	75
76	63.74	41.39	63.56	41.67	63.38	41.95	63.19	42.22	76
77	64.58	41.94	64.39	42.22	64.21	42.50	64.02	42.78	77
78	65.42	42.48	65.23	42.77	65.04	43.05	64.85	43.33	78
79	66.25	43.03	66.07	43.32	65.88	43.60	65.69	43.89	79
80	67.09	43.57	66.90	43.86	66.71	44.15	66.52	44.45	80
81	67.93	44.12	67.74	44.41	67.54	44.71	67.35	45.00	81
82	68.77	44.66	68.58	44.96	68.38	45.26	68.18	45.56	82
83	69.61	45.20	69.41	45.51	69.21	45.81	69.01	46.11	83
84	70.45	45.75	70.25	46.06	70.05	46.36	69.84	46.67	84
85	71.29	46.29	71.08	46.60	70.88	46.91	70.67	47.22	85
86	72.13	46.84	71.92	47.15	71.71	47.47	71.51	47.78	86
87	72.96	47.38	72.76	47.70	72.55	48.02	72.34	48.33	87
88	73.80	47.93	73.59	48.25	73.38	48.57	73.17	48.89	88
89	74.64	48.47	74.43	48.80	74.22	49.12	74.00	49.45	89
90	75.48	49.02	75.27	49.35	75.05	49.67	74.83	50.00	90
91	76.32	49.56	76.10	49.89	75.88	50.23	75.66	50.56	91
92	77.16	50.11	76.94	50.44	76.72	50.78	76.50	51.11	92
93	78.00	50.65	77.77	50.99	77.55	51.33	77.33	51.67	93
94	78.83	51.20	78.61	51.54	78.39	51.88	78.16	52.22	94
95	79.67	51.74	79.45	52.09	79.22	52.43	78.99	52.78	95
96	80.51	52.29	80.28	52.64	80.05	52.99	79.82	53.33	96
97	81.35	52.83	81.12	53.18	80.89	53.54	80.65	53.89	97
98	82.19	53.37	81.96	53.73	81.72	54.09	81.48	54.45	98
99	83.03	53.92	82.79	54.28	82.55	54.64	82.32	55.00	99
100	83.87	54.46	83.63	54.83	83.39	55.19	83.15	55.56	00
Distance.	Dep.	Lat.	Dep.	Lat.	Dep	Lat.	Dep	Lat.	Distance.
	57 Deg.		56¾ Deg.		56½ Deg.		56¼ Deg.		

Distance.	34 Deg.		34¼ Deg.		34½ Deg.		34¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.83	0.56	0.83	0.56	0.82	0.57	0.82	0.57	1
2	1.66	1.12	1.65	1.13	1.65	1.13	1.64	1.14	2
3	2.49	1.68	2.48	1.69	2.47	1.70	2.46	1.71	3
4	3.32	2.24	3.31	2.25	3.30	2.27	3.29	2.28	4
5	4.15	2.80	4.13	2.81	4.12	2.83	4.11	2.85	5
6	4.97	3.36	4.96	3.38	4.94	3.40	4.93	3.42	6
7	5.80	3.91	5.79	3.94	5.77	3.96	5.75	3.99	7
8	6.63	4.47	6.61	4.50	6.59	4.53	6.57	4.56	8
9	7.46	5.03	7.44	5.07	7.42	5.10	7.39	5.13	9
10	8.29	5.59	8.27	5.63	8.24	5.66	8.22	5.70	10
11	9.12	6.15	9.09	6.19	9.07	6.23	9.04	6.27	11
12	9.95	6.71	9.92	6.75	9.89	6.80	9.86	6.84	12
13	10.78	7.27	10.75	7.32	10.71	7.36	10.68	7.41	13
14	11.61	7.83	11.57	7.88	11.54	7.93	11.50	7.98	14
15	12.44	8.39	12.40	8.44	12.36	8.50	12.32	8.55	15
16	13.26	8.95	13.23	9.00	13.19	9.06	13.15	9.12	16
17	14.09	9.51	14.05	9.57	14.01	9.63	13.97	9.69	17
18	14.92	10.07	14.88	10.13	14.83	10.20	14.79	10.26	18
19	15.75	10.62	15.71	10.69	15.66	10.76	15.61	10.83	19
20	16.58	11.18	16.53	11.26	16.48	11.33	16.43	11.40	20
21	17.41	11.74	17.36	11.82	17.31	11.89	17.25	11.97	21
22	18.24	12.30	18.18	12.38	18.13	12.46	18.08	12.54	22
23	19.07	12.86	19.01	12.94	18.95	13.03	18.90	13.11	23
24	19.90	13.42	19.84	13.51	19.78	13.59	19.72	13.68	24
25	20.73	13.98	20.66	14.07	20.60	14.16	20.54	14.25	25
26	21.55	14.54	21.49	14.63	21.43	14.73	21.36	14.82	26
27	22.38	15.10	22.32	15.20	22.25	15.29	22.18	15.39	27
28	23.21	15.66	23.14	15.76	23.08	15.86	23.01	15.96	28
29	24.04	16.22	23.97	16.32	23.90	16.43	23.83	16.53	29
30	24.87	16.78	24.80	16.88	24.72	16.99	24.65	17.10	30
31	25.70	17.33	25.62	17.45	25.55	17.56	25.47	17.67	31
32	26.53	17.89	26.45	18.01	26.37	18.12	26.29	18.24	32
33	27.36	18.45	27.28	18.57	27.20	18.69	27.11	18.81	33
34	28.19	19.01	28.10	19.14	28.02	19.26	27.94	19.38	34
35	29.02	19.57	28.93	19.70	28.84	19.82	28.76	19.95	35
36	29.85	20.13	29.76	20.26	29.67	20.39	29.58	20.52	36
37	30.67	20.69	30.58	20.82	30.49	20.96	30.40	21.09	37
38	31.50	21.25	31.41	21.39	31.32	21.52	31.22	21.66	38
39	32.33	21.81	32.24	21.95	32.14	22.09	32.04	22.23	39
40	33.16	22.37	33.06	22.51	32.97	22.66	32.87	22.80	40
41	33.99	22.93	33.89	23.07	33.79	23.22	33.69	23.37	41
42	34.82	23.49	34.72	23.64	34.61	23.79	34.51	23.94	42
43	35.65	24.05	35.54	24.20	35.44	24.36	35.33	24.51	43
44	36.48	24.60	36.37	24.76	36.26	24.92	36.15	25.08	44
45	37.31	25.16	37.20	25.33	37.09	25.49	36.97	25.65	45
46	38.14	25.72	38.02	25.89	37.91	26.05	37.80	26.22	46
47	38.96	26.28	38.85	26.45	38.73	26.62	38.62	26.79	47
48	39.79	26.84	39.68	27.01	39.56	27.19	39.44	27.36	48
49	40.62	27.40	40.50	27.58	40.38	27.75	40.26	27.93	49
50	41.45	27.96	41.33	28.14	41.21	28.32	41.08	28.50	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	56 Deg.		55¾ Deg.		55½ Deg.		55¼ Deg.		

Distance.	34 Deg.		34¼ Deg.		34½ Deg.		34¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	42.28	28.52	42.16	28.70	42.03	28.89	41.90	29.07	51
52	43.11	29.08	42.98	29.27	42.85	29.45	42.73	29.64	52
53	43.94	29.64	43.81	29.83	43.68	30.02	43.55	30.21	53
54	44.77	30.20	44.64	30.39	44.50	30.59	44.37	30.78	54
55	45.60	30.76	45.46	30.95	45.33	31.15	45.19	31.35	55
56	46.43	31.31	46.29	31.52	46.15	31.72	46.01	31.92	56
57	47.26	31.87	47.12	32.08	46.98	32.29	46.83	32.49	57
58	48.08	32.43	47.94	32.64	47.80	32.85	47.66	33.06	58
59	48.91	32.99	48.77	33.21	48.62	33.42	48.48	33.63	59
60	49.74	33.55	49.60	33.77	49.45	33.98	49.30	34.20	60
61	50.57	34.11	50.42	34.33	50.27	34.55	50.12	34.77	61
62	51.40	34.67	51.25	34.89	51.10	35.12	50.94	35.34	62
63	52.23	35.23	52.08	35.46	51.92	35.68	51.76	35.91	63
64	53.06	35.79	52.90	36.02	52.74	36.25	52.59	36.48	64
65	53.89	36.35	53.73	36.58	53.57	36.82	53.41	37.05	65
66	54.72	36.91	54.55	37.15	54.39	37.38	54.23	37.62	66
67	55.55	37.46	55.38	37.71	55.22	37.95	55.05	38.19	67
68	56.37	38.03	56.21	38.27	56.04	38.52	55.87	38.76	68
69	57.20	38.58	57.03	38.83	56.86	39.08	56.69	39.33	69
70	58.03	39.14	57.86	39.40	57.69	39.65	57.52	39.90	70
71	58.86	39.70	58.69	39.96	58.51	40.21	58.34	40.47	71
72	59.69	40.26	59.51	40.52	59.34	40.78	59.16	41.04	72
73	60.52	40.82	60.34	41.08	60.16	41.35	59.98	41.61	73
74	61.35	41.38	61.17	41.65	60.99	41.91	60.80	42.18	74
75	62.18	41.94	61.99	42.21	61.81	42.48	61.62	42.75	75
76	63.01	42.50	62.82	42.77	62.63	43.05	62.45	43.32	76
77	63.84	43.06	63.65	43.34	63.46	43.61	63.27	43.89	77
78	64.66	43.62	64.47	43.90	64.28	44.18	64.09	44.46	78
79	65.49	44.18	65.30	44.46	65.11	44.75	64.91	45.03	79
80	66.32	44.74	66.13	45.02	65.93	45.31	65.73	45.60	80
81	67.15	45.29	66.95	45.59	66.75	45.88	66.55	46.17	81
82	67.98	45.85	67.78	46.15	67.58	46.45	67.37	46.74	82
83	68.81	46.41	68.61	46.71	68.40	47.01	68.20	47.31	83
84	69.64	46.97	69.43	47.28	69.23	47.58	69.02	47.88	84
85	70.47	47.53	70.26	47.84	70.05	48.14	69.84	48.45	85
86	71.30	48.09	71.09	48.40	70.87	48.71	70.66	49.02	86
87	72.13	48.65	71.91	48.96	71.70	49.28	71.48	49.59	87
88	72.96	49.21	72.74	49.53	72.52	49.84	72.30	50.16	88
89	73.78	49.77	73.57	50.09	73.35	50.41	73.13	50.73	89
90	74.61	50.33	74.39	50.65	74.17	50.98	73.95	51.30	90
91	75.44	50.89	75.22	51.22	75.00	51.54	74.77	51.87	91
92	76.27	51.45	76.05	51.78	75.82	52.11	75.59	52.44	92
93	77.10	52.00	76.87	52.34	76.64	52.68	76.41	53.01	93
94	77.93	52.56	77.70	52.90	77.47	53.24	77.23	53.58	94
95	78.76	53.12	78.53	53.47	78.29	53.81	78.06	54.15	95
96	79.59	53.68	79.35	54.03	79.12	54.37	78.88	54.72	96
97	80.42	54.24	80.18	54.59	79.94	54.94	79.70	55.29	97
98	81.25	54.80	81.01	55.15	80.76	55.51	80.52	55.86	98
99	82.07	55.36	81.83	55.72	81.59	56.07	81.34	56.43	99
100	82.90	55.92	82.66	56.28	82.41	56.64	82.16	57.00	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep	Lat.	Dep.	Lat.	Distance.
	56 Deg.		55¾ Deg.		55½ Deg.		55¼ Deg.		

Distance.	35 Deg.		35¼ Deg		35½ Deg.		35¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.82	0.57	0.82	0.58	0.81	0.58	0.81	0.58	1
2	1.64	1.15	1.63	1.15	1.63	1.16	1.62	1.17	2
3	2.46	1.72	2.45	1.73	2.44	1.74	2.43	1.75	3
4	3.28	2.29	3.27	2.31	3.26	2.32	3.25	2.34	4
5	4.10	2.87	4.08	2.89	4.07	2.90	4.06	2.92	5
6	4.91	3.44	4.90	3.46	4.88	3.48	4.87	3.51	6
7	5.73	4.01	5.72	4.04	5.70	4.06	5.68	4.09	7
8	6.55	4.59	6.53	4.62	6.51	4.65	6.49	4.67	8
9	7.37	5.16	7.35	5.19	7.33	5.23	7.30	5.26	9
10	8.19	5.74	8.17	5.77	8.14	5.81	8.12	5.84	10
11	9.01	6.31	8.98	6.35	8.96	6.39	8.93	6.43	11
12	9.83	6.88	9.80	6.93	9.77	6.97	9.74	7.01	12
13	10.65	7.46	10.62	7.50	10.58	7.55	10.55	7.60	13
14	11.47	8.03	11.43	8.08	11.40	8.13	11.36	8.18	14
15	12.29	8.60	12.25	8.66	12.21	8.71	12.17	8.76	15
16	13.11	9.18	13.07	9.23	13.03	9.29	12.99	9.35	16
17	13.93	9.75	13.88	9.81	13.84	9.87	13.80	9.93	17
18	14.74	10.32	14.70	10.39	14.65	10.45	14.61	10.52	18
19	15.56	10.90	15.52	10.97	15.47	11.03	15.42	11.10	19
20	16.38	11.47	16.33	11.54	16.28	11.61	16.23	11.68	20
21	17.20	12.05	17.15	12.12	17.10	12.19	17.04	12.27	21
22	18.02	12.62	17.97	12.70	17.91	12.78	17.85	12.85	22
23	18.84	13.19	18.78	13.27	18.72	13.36	18.67	13.44	23
24	19.66	13.77	19.60	13.85	19.54	13.94	19.48	14.02	24
25	20.48	14.34	20.42	14.43	20.35	14.52	20.29	14.61	25
26	21.30	14.91	21.23	15.01	21.17	15.10	21.10	15.19	26
27	22.12	15.49	22.05	15.58	21.98	15.68	21.91	15.77	27
28	22.94	16.06	22.87	16.15	22.80	16.26	22.72	16.36	28
29	23.76	16.63	23.68	16.74	23.61	16.84	23.54	16.94	29
30	24.57	17.21	24.50	17.51	24.42	17.42	24.35	17.53	30
31	25.39	17.78	25.32	17.89	25.24	18.00	25.16	18.11	31
32	26.21	18.35	26.13	18.47	26.05	18.58	25.97	18.70	32
33	27.03	18.93	26.95	19.05	26.87	19.16	26.78	19.28	33
34	27.85	19.50	27.77	19.62	27.68	19.74	27.59	19.86	34
35	28.67	20.08	28.58	20.20	28.49	20.32	28.41	20.45	35
36	29.49	20.65	29.40	20.78	29.31	20.91	29.22	21.03	36
37	30.31	21.22	30.22	21.35	30.12	21.49	30.03	21.62	37
38	31.13	21.80	31.03	21.93	30.94	22.07	30.84	22.20	38
39	31.95	22.37	31.85	22.51	31.75	22.65	31.65	22.79	39
40	32.77	22.94	32.67	23.09	32.56	23.23	32.46	23.37	40
41	33.59	23.52	33.48	23.66	33.38	23.81	33.27	23.95	41
42	34.40	24.09	34.30	24.24	34.19	24.39	34.09	24.54	42
43	35.22	24.66	35.12	24.82	35.01	24.97	34.90	25.12	43
44	36.04	25.24	35.93	25.39	35.82	25.55	35.71	25.71	44
45	36.86	25.81	36.75	25.97	36.64	26.13	36.52	26.29	45
46	37.68	26.38	37.57	26.55	37.45	26.71	37.33	26.88	46
47	38.50	26.96	38.38	27.13	38.26	27.29	38.14	27.46	47
48	39.32	27.53	39.20	27.70	39.08	27.87	38.96	28.04	48
49	40.14	28.11	40.02	28.28	39.89	28.45	39.77	28.63	49
50	40.96	28.68	40.83	28.86	40.71	29.04	40.58	29.21	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	55 Deg		54¾ Deg.		54½ Deg.		54¼ Deg		

Distance.	35 Deg.		35¼ Deg.		35½ Deg.		35¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	41.78	29.25	41.65	29.43	41.52	29.62	41.39	29.80	51
52	42.60	29.82	42.47	30.01	42.33	30.20	42.20	30.38	52
53	43.42	30.40	43.28	30.59	43.15	30.78	43.01	30.97	53
54	44.22	30.97	44.10	31.17	43.96	31.36	43.82	31.55	54
55	45.05	31.55	44.92	31.74	44.78	31.94	44.64	32.13	55
56	45.87	32.12	45.73	32.32	45.59	32.52	45.45	32.72	56
57	46.69	32.69	46.55	32.90	46.40	33.10	46.26	33.30	57
58	47.51	33.27	47.37	33.47	47.22	33.68	47.07	33.89	58
59	48.33	33.84	48.18	34.05	48.03	34.26	47.88	34.47	59
60	49.15	34.41	49.00	34.63	48.85	34.84	48.69	35.05	60
61	49.97	34.99	49.82	35.21	49.66	35.42	49.51	35.64	61
62	50.79	35.56	50.63	35.78	50.48	36.00	50.32	36.22	62
63	51.61	36.14	51.45	36.36	51.29	36.58	51.13	36.81	63
64	52.43	36.71	52.27	36.94	52.10	37.16	51.94	37.39	64
65	53.24	37.28	53.08	37.51	52.92	37.75	52.75	37.98	65
66	54.06	37.86	53.90	38.09	53.73	38.33	53.56	38.56	66
67	54.88	38.43	54.71	38.67	54.55	38.91	54.38	39.14	67
68	55.70	39.00	55.53	39.25	55.36	39.49	55.19	39.73	68
69	56.52	39.58	56.35	39.82	56.17	40.07	56.00	40.31	69
70	57.34	40.15	57.16	40 40	56.99	40.65	56.81	40.90	70
71	58.16	40.72	57.98	40.98	57.80	41.23	57.62	41.48	71
72	58.98	41.30	58.80	41.55	58.62	41.81	58.43	42.07	72
73	59.80	41.87	59.61	42.13	59.43	42.39	59.24	42.65	73
74	60.62	42.44	60.43	42.71	60.24	42.97	60.06	43.23	74
75	61.44	43.02	61.25	43.29	61.06	43.55	60.87	43.82	75
76	62.26	43.59	62.06	43.86	61.87	44.13	61.68	44.40	76
77	63.07	44.17	62.88	44.44	62.69	44.71	62.49	44.99	77
78	63.89	44.74	63.70	45.02	63.50	45.29	63.30	45.57	78
79	64.71	45.31	64.51	45.59	64.32	45.88	64.11	46.16	79
80	65.53	45.89	65.33	46.17	65.13	46.46	64.93	46.74	80
81	66.35	46.46	66.15	46.75	65.94	47.04	65.74	47.32	81
82	67.17	47.03	66.96	47.33	66.76	47.62	66.55	47.91	82
83	67.99	47.61	67.78	47.90	67.57	48.20	67.36	48.49	83
84	68.81	48.18	68.60	48.48	68.39	48.78	68.17	49.08	84
85	69.63	48.75	69.41	49.06	69.20	49.36	68.98	49.66	85
86	70.45	49.33	70.23	49.63	70.01	49.94	69.80	50.25	86
87	71.27	49.90	71.05	50.21	70.83	50.52	70.61	50.83	87
88	72.09	50 47	71.86	50.79	71.64	51.10	71.42	51.41	88
89	72.90	51.05	72.68	51.37	72.46	51.68	72.23	52.00	89
90	73.72	51.62	73.50	51.94	73.27	52.26	73.04	52.58	90
91	74.54	52.20	74.31	52.52	74.08	52.84	73.85	53.17	91
92	75.36	52.77	75.13	53.10	74.90	53.42	74.66	53.75	92
93	76.18	53.34	75.95	53.67	75.71	54.01	75.48	54.34	93
94	77.00	53.92	76.76	54.25	76.53	54.59	76.29	54.92	94
95	77.82	54.49	77.58	54.83	77.34	55.17	77 10	55.50	95
96	78.64	55.06	78.40	55.41	78.16	55.75	77.91	56.09	96
97	79.46	55.64	79.21	55.98	78 97	56.33	78.72	56.67	97
98	80.28	56.21	80.03	56.56	79.78	56.91	79.53	57.26	98
99	81.10	56.78	80.85	57.14	80.60	57.49	80.35	57.84	99
100	81.92	57 36	81.66	57.71	81.41	58.07	81.16	58.42	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	55 Deg.		54¾ Deg.		54½ Deg.		54¼ Deg.		

Distance.	36 Deg.		36¼ Deg.		36½ Deg.		36¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.81	0.59	0.81	0.59	0.80	0.59	0.80	0.60	1
2	1.62	1.18	1.61	1.18	1.61	1.19	1.60	1.20	2
3	2.43	1.76	2.42	1.77	2.41	1.78	2.40	1.79	3
4	3.24	2.35	3.23	2.37	3.22	2.38	3.20	2.39	4
5	4.05	2.94	4.03	2.96	4.02	2.97	4.01	2.99	5
6	4.85	3.53	4.84	3.55	4.82	3.57	4.81	3.59	6
7	5.66	4.11	5.65	4.14	5.63	4.16	5.61	4.19	7
8	6.47	4.70	6.45	4.73	6.43	4.76	6.41	4.79	8
9	7.28	5.29	7.26	5.32	7.23	5.35	7.21	5.38	9
10	8.09	5.88	8.06	5.91	8.04	5.95	8.01	5.98	10
11	8.90	6.47	8.87	6.50	8.84	6.54	8.81	6.58	11
12	9.71	7.05	9.68	7.10	9.65	7.14	9.61	7.18	12
13	10.52	7.64	10.48	7.69	10.45	7.73	10.42	7.78	13
14	11.33	8.23	11.29	8.28	11.25	8.33	11.22	8.38	14
15	12.14	8.82	12.10	8.87	12.06	8.92	12.02	8.97	15
16	12.94	9.40	12.90	9.46	12.86	9.52	12.82	9.57	16
17	13.75	9.99	13.71	10.05	13.67	10.11	13.62	10.17	17
18	14.56	10.58	14.52	10.64	14.47	10.71	14.42	10.77	18
19	15.37	11.17	15.32	11.23	15.27	11.30	15.22	11.37	19
20	16.18	11.76	16.13	11.83	16.08	11.90	16.03	11.97	20
21	16.99	12.34	16.94	12.42	16.88	12.49	16.83	12.56	21
22	17.80	12.93	17.74	13.01	17.68	13.09	17.63	13.16	22
23	18.61	13.52	18.55	13.60	18.49	13.68	18.43	13.76	23
24	19.42	14.11	19.35	14.19	19.29	14.28	19.23	14.36	24
25	20.23	14.69	20.16	14.78	20.10	14.87	20.03	14.96	25
26	21.03	15.28	20.97	15.37	20.90	15.47	20.83	15.56	26
27	21.84	15.87	21.77	15.97	21.70	16.06	21.63	16.15	27
28	22.65	16.46	22.58	16.56	22.51	16.65	22.44	16.75	28
29	23.46	17.05	23.39	17.15	23.31	17.25	23.24	17.35	29
30	24.27	17.63	24.19	17.74	24.12	17.84	24.04	17.95	30
31	25.08	18.22	25.00	18.33	24.92	18.44	24.84	18.55	31
32	25.89	18.81	25.81	18.92	25.72	19.03	25.64	19.15	32
33	26.70	19.40	26.61	19.51	26.53	19.63	26.44	19.74	33
34	27.51	19.98	27.42	20.10	27.33	20.22	27.24	20.34	34
35	28.32	20.57	28.23	20.70	28.13	20.82	28.04	20.94	35
36	29.12	21.16	29.03	21.29	28.94	21.41	28.85	21.54	36
37	29.93	21.75	29.84	21.88	29.74	22.01	29.65	22.14	37
38	30.74	22.34	30.64	22.47	30.55	22.60	30.45	22.74	38
39	31.55	22.92	31.45	23.06	31.35	23.20	31.25	23.33	39
40	32.36	23.51	32.26	23.65	32.15	23.79	32.05	23.93	40
41	33.17	24.10	33.06	24.24	32.96	24.39	32.85	24.53	41
42	33.98	24.69	33.87	24.83	33.76	24.98	33.65	25.13	42
43	34.79	25.27	34.68	25.43	34.57	25.58	34.45	25.73	43
44	35.60	25.86	35.48	26.02	35.37	26.17	35.26	26.33	44
45	36.41	26.45	36.29	26.61	36.17	26.77	36.06	26.92	45
46	37.21	27.04	37.10	27.20	36.98	27.36	36.86	27.52	46
47	38.02	27.63	37.90	27.79	37.78	27.96	37.66	28.12	47
48	38.83	28.21	38.71	28.38	38.59	28.55	38.46	28.72	48
49	39.64	28.80	39.52	28.97	39.39	29.15	39.26	29.32	49
50	40.45	29.39	40.32	29.57	40.19	29.74	40.06	29.92	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	54 Deg.		53¾ Deg.		53½ Deg.		53¼ Deg.		

Distance.	36 Deg.		36¼ Deg.		36½ Deg.		36¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat	Dep	Lat.	Dep.	
51	41.26	29.98	41.13	30.16	41.00	30.34	40.86	30.51	51
52	42.07	30.56	41.94	30.75	41.80	30.93	41.67	31.11	52
53	42.88	31.15	42.74	31.34	42.60	31.53	42.47	31.71	53
54	43.69	31.74	43.55	31.93	43.41	32.12	43.27	32.31	54
55	44.50	32.33	44.35	32.52	44.21	32.72	44.07	32.91	55
56	45.30	32.92	45.16	33.11	45.02	33.31	44.87	33.51	56
57	46.11	33.50	45.97	33.70	45.82	33.90	45.67	34.10	57
58	46.92	34.09	46.77	34.30	46.62	34.50	46.47	34.70	58
59	47.73	34.68	47.58	34.89	47.43	35.09	47.27	35.30	59
60	48.54	35.27	48.39	35.48	48.23	35.69	48.08	35.90	60
61	49.35	35.85	49.19	36.07	49.04	36.28	48.88	36.50	61
62	50.16	36.44	50.00	36.66	49.84	36.88	49.68	37.10	62
63	50.97	37.03	50.81	37.25	50.64	37.47	50.48	37.69	63
64	51.78	37.62	51.61	37.84	51.45	38.07	51.28	38.29	64
65	52.59	38.21	52.42	38.44	52.25	38.66	52.08	38.89	65
66	53.40	38.79	53.23	39.03	53.05	39.26	52.88	39.49	66
67	54.20	39.38	54.03	39.62	53.86	39.85	53.68	40.09	67
68	55.01	39.97	54.84	40.21	54.66	40.45	54.49	40.69	68
69	55.82	40.56	55.64	40.80	55.47	41.04	55.29	41.28	69
70	56.63	41.14	56.45	41.39	56.27	41.64	56.09	41.88	70
71	57.44	41.73	57.26	41.98	57.07	42.23	56.89	42.48	71
72	58.25	42.32	58.06	42.57	57.88	42.83	57.69	43.08	72
73	59.06	42.91	58.87	43.17	58.68	43.42	58.49	43.68	73
74	59.87	43.50	59.68	43.76	59.49	44.02	59.29	44.28	74
75	60.68	44.08	60.48	44.35	60.29	44.61	60.09	44.87	75
76	61.49	44.67	61.29	44.94	61.09	45.21	60.90	45.47	76
77	62.29	45.26	62.10	45.53	61.90	45.80	61.70	46.07	77
78	63.10	45.85	62.90	46.12	62.70	46.40	62.50	46.67	78
79	63.91	46.43	63.71	46.71	63.50	46.99	63.30	47.27	79
80	64.72	47.02	64.52	47.30	64.31	47.59	64.10	47.87	80
81	65.53	47.61	65.32	47.90	65.11	48.18	64.90	48.46	81
82	66.34	48.20	66.13	48.49	65.92	48.78	65.70	49.06	82
83	67.15	48.79	66.93	49.08	66.72	49.37	66.50	49.66	83
84	67.96	49.37	67.74	49.67	67.52	49.97	67.31	50.26	84
85	68.77	49.96	68.55	50.26	68.33	50.56	68.11	50.86	85
86	69.58	50.55	69.35	50.85	69.13	51.15	68.91	51.46	86
87	70.38	51.14	70.16	51.44	69.94	51.75	69.71	52.05	87
88	71.19	51.73	70.97	52.04	70.74	52.34	70.51	52.65	88
89	72.00	52.31	71.77	52.63	71.54	52.94	71.31	53.25	89
90	72.81	52.90	72.58	53.22	72.35	53.53	72.11	53.85	90
91	73.62	53.49	73.39	53.81	73.15	54.13	72.91	54.45	91
92	74.43	54.08	74.19	54.40	73.95	54.72	73.72	55.05	92
93	75.24	54.66	75.00	54.99	74.76	55.32	74.52	55.64	93
94	76.05	55.25	75.81	55.58	75.56	55.91	75.32	56.24	94
95	76.86	55.84	76.61	56.17	76.37	56.51	76.12	56.84	95
96	77.67	56.43	77.42	56.77	77.17	57.10	76.92	57.44	96
97	78.47	57.02	78.23	57.36	77.97	57.70	77.72	58.04	97
98	79.28	57.60	79.03	57.95	78.78	58.29	78.52	58.64	98
99	80.09	58.19	79.84	58.54	79.58	58.89	79.32	59.23	99
100	80.90	58.78	80.64	59.13	80.39	59.48	80.13	59.83	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep	Lat.	Distance.
	54 Deg.		53¾ Deg.		53½ Deg		53¼ Deg.		

Distance.	37 Deg.		37¼ Deg.		37½ Deg.		37¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep	
1	0.80	0.60	0.80	0.61	0.79	0.61	0.79	0 61	
2	1.60	1.20	1.59	1.21	1.59	1.22	1.58	1.22	2
3	2.40	1.81	2.39	1.82	2.38	1.83	2.37	1.84	3
4	3.19	2.41	3.18	2.42	3.17	2 43	3.16	2.45	4
5	3.99	3.01	3.98	3.03	3.97	3.04	3.95	3.06	5
6	4.79	3.61	4.78	3 63	4.76	3.65	4.74	3.67	6
7	5.59	4.21	5.57	4.24	5.55	4.26	5.53	4.29	7
8	6.39	4.81	6.37	4.84	6.35	4.87	6.33	4.90	8
9	7.19	5.42	7.16	5 45	7.14	5.48	7.12	5.51	9
10	7.99	6.02	7.96	6.05	7.93	6.09	7.91	6.12	10
11	8.78	6.62	8.76	6.66	8.73	6.70	8.70	6.73	11
12	9.58	7.22	9.55	7.26	9.52	7.31	9.49	7.35	12
13	10.38	7.82	10.35	7.87	10.31	7.91	10.28	7.96	13
14	11.18	8.43	11.14	8.47	11.11	8.52	11.07	8.57	14
15	11.98	9.03	11.94	9.08	11.90	9.13	11.86	9.18	15
16	12.78	9.63	12.74	9.68	12.69	9.74	12.65	9.80	16
17	13.58	10.23	13.53	10.29	13.49	10.35	13.44	10.41	17
18	14.38	10.83	14.33	10.90	14.28	10.96	14.23	11.02	18
19	15.17	11.43	15.12	11.50	15.07	11.57	15.02	11.63	19
20	15.97	12.04	15.92	12.11	15.87	12.18	15.81	12.24	20
21	16.77	12.64	16.72	12.71	16.66	12.78	16.60	12.86	21
22	17.57	13.24	17.51	13.32	17.45	13.39	17.40	13.47	22
23	18.37	13.84	18.31	13.92	18.25	14.00	18.19	14.08	23
24	19.17	14.44	19.10	14.53	19.04	14.61	18.98	14.69	24
25	19.97	15.05	19.90	15.13	19.83	15.22	19.77	15.31	25
26	20.76	15.65	20.70	15.74	20.63	15.83	20.56	15.92	26
27	21.56	16.25	21.49	16.34	21.42	16.44	21.35	16.53	27
28	22.36	16.85	22.29	16.95	22.21	17.05	22.14	17.14	28
29	23.16	17.45	23.08	17.55	23.01	17.65	22.93	17.75	29
30	23.96	18.05	23.88	18.16	23.80	18.26	23.72	18.37	30
31	24.76	18.66	24.68	18.76	24.59	18.87	24.51	18.98	31
32	25.56	19.26	25.47	19.37	25.39	19.48	25.30	19.59	32
33	26.35	19.86	26.27	19.97	26.18	20.09	26.09	20.20	33
34	27.15	20.46	27.06	20.58	26.97	20.70	26.88	20.82	34
35	27.95	21.06	27.86	21.19	27.77	21.31	27.67	21.43	35
36	28.75	21.67	28.66	21.79	28.56	21.92	28.46	22.04	36
37	29.55	22.27	29.45	22.40	29.35	22.52	29.26	22.65	37
38	30.35	22.87	30.25	23.00	30.15	23.13	30.05	23.26	38
39	31.15	23.47	31.04	23.61	30.94	23.74	30.84	23.88	39
40	31.95	24.07	31.84	24.21	31.73	24.35	31.63	24.49	40
41	32.74	24.67	32.64	24.82	32 53	24.96	32.42	25.10	41
42	33.54	25.28	33.43	25.42	33 32	25.57	33.21	25.71	42
43	34.34	25.88	34.23	26.03	34.11	26.18	34.00	26.33	43
44	35.14	26.48	35.02	26.63	34.91	26.79	34.79	26.94	44
45	35.94	27 08	35.82	27.24	35.70	27.39	35.58	27.55	45
46	36.74	27.68	36.62	27.84	36.49	28.00	36.37	28.16	46
47	37.54	28.29	37.41	28.45	37.29	28.61	37.16	28 77	47
48	38.33	28.89	38.21	29.05	38.08	29.22	37.95	29.39	48
49	39.13	29.49	39.00	29.66	38.87	29.83	38.74	30.00	49
50	39.93	30.09	39.80	30.26	39.67	30.44	39.53	30.61	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	53 Deg.		52¾ Deg.		52½ Deg		52¼ Deg.		

Distance.	37 Deg.		37¼ Deg.		37½ Deg.		37¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	40.73	30.69	40.60	30.87	40.46	31.05	40.33	31.22	51
52	41.53	31.29	41.39	31.48	41.25	31.66	41.12	31.84	52
53	42.33	31.90	42.19	32.08	42.05	32.26	41.91	32.45	53
54	43.13	32.50	42.98	32.69	42.84	32.87	42.70	33.06	54
55	43.92	33.10	43.78	33.29	43.63	33.48	43.49	33.67	55
56	44.72	33.70	44.58	33.90	44.43	34.09	44.28	34.28	56
57	45.52	34.30	45.37	34.50	45.22	34.70	45.07	34.90	57
58	46.32	34.91	46.17	35.11	46.01	35.31	45.86	35.51	58
59	47.12	35.51	46.96	35.71	46.81	35.92	46.65	36.12	59
60	47.92	36.11	47.76	36.32	47.60	36.53	47.44	36.73	60
61	48.72	36.71	48.56	36.92	48.39	37.13	48.23	37.35	61
62	49.52	37.31	49.35	37.53	49.19	37.74	49.02	37.96	62
63	50.31	37.91	50.15	38.13	49.98	38.35	49.81	38.57	63
64	51.11	38.52	50.94	38.74	50.77	38.96	50.60	39.18	64
65	51.91	39.12	51.74	39.34	51.57	39.57	51.39	39.79	65
66	52.71	39.72	52.54	39.95	52.36	40.18	52.19	40.41	66
67	53.51	40.32	53.33	40.55	53.15	40.79	52.98	41.02	67
68	54.31	40.92	54.13	41.16	53.95	41.40	53.77	41.63	68
69	55.11	41.53	54.92	41.77	54.74	42.00	54.56	42.24	69
70	55.90	42.13	55.72	42.37	55.53	42.61	55.35	42.86	70
71	56.70	42.73	56.52	42.98	56.33	43.22	56.14	43.47	71
72	57.50	43.33	57.31	43.58	57.12	43.83	56.93	44.08	72
73	58.30	43.93	58.11	44.19	57.91	44.44	57.72	44.69	73
74	59.10	44.53	58.90	44.79	58.71	45.05	58.51	45.30	74
75	59.90	45.14	59.70	45.40	59.50	45.66	59.30	45.92	75
76	60.70	45.74	60.50	46.00	60.29	46.27	60.09	46.53	76
77	61.49	46.34	61.29	46.61	61.09	46.87	60.88	47.14	77
78	62.29	46.94	62.09	47.21	61.88	47.48	61.67	47.75	78
79	63.09	47.54	62.88	47.82	62.67	48.09	62.46	48.37	79
80	63.89	48.15	63.68	48.42	63.47	48.70	63.26	48.98	80
81	64.69	48.75	64.48	49.03	64.26	49.31	64.05	49.59	81
82	65.49	49.35	65.27	49.63	65.05	49.92	64.84	50.20	82
83	66.29	49.95	66.07	50.24	65.85	50.53	65.63	50.81	83
84	67.09	50.55	66.86	50.84	66.64	51.14	66.42	51.43	84
85	67.88	51.15	67.66	51.45	67.43	51.74	67.21	52.04	85
86	68.68	51.76	68.46	52.06	68.23	52.35	68.00	52.65	86
87	69.48	52.36	69.25	52.66	69.02	52.96	68.79	53.26	87
88	70.28	52.96	70.05	53.27	69.82	53.57	69.58	53.88	88
89	71.08	53.56	70.84	53.87	70.61	54.18	70.37	54.49	89
90	71.88	54.16	71.64	54.48	71.40	54.79	71.16	55.10	90
91	72.68	54.77	72.44	55.08	72.20	55.40	71.95	55.71	91
92	73.47	55.37	73.23	55.69	72.99	56.01	72.74	56.32	92
93	74.27	55.97	74.03	56.29	73.78	56.61	73.53	56.94	93
94	75.07	56.57	74.82	56.90	74.58	57.22	74.32	57.55	94
95	75.87	57.17	75.62	57.50	75.37	57.83	75.12	58.16	95
96	76.67	57.77	76.42	58.11	76.16	58.44	75.91	58.77	96
97	77.47	58.38	77.21	58.71	76.96	59.05	76.70	59.39	97
98	78.27	58.98	78.01	59.32	77.75	59.66	77.49	60.00	98
99	79.06	59.58	78.80	59.92	78.54	60.27	78.28	60.61	99
100	79.86	60.18	79.60	60.53	79.34	60.88	79.07	61.22	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	53 Deg.		52¾ Deg.		52½ Deg.		52¼ Deg.		

Distance.	38 Deg.		38¼ Deg.		38½ Deg.		38¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.79	0.62	0.79	0.62	0.78	0.62	0.78	0.63	1
2	1.58	1.23	1.57	1.24	1.57	1.24	1.56	1.25	2
3	2.36	1.85	2.36	1.86	2.35	1.87	2.34	1.88	3
4	3.15	2.46	3.14	2.48	3.13	2.49	3.12	2.50	4
5	3.94	3.08	3.93	3.10	3.91	3.11	3.90	3.13	5
6	4.73	3.69	4.71	3.71	4.70	3.74	4.68	3.76	6
7	5.52	4.31	5.50	4.33	5.48	4.36	5.46	4.38	7
8	6.30	4.93	6.28	4.95	6.26	4.98	6.24	5.01	8
9	7.09	5.54	7.07	5.57	7.04	5.60	7.02	5.63	9
10	7.88	6.16	7.85	6.19	7.83	6.23	7.80	6.26	10
11	8.67	6.77	8.64	6.81	8.61	6.85	8.58	6.89	11
12	9.46	7.39	9.42	7.43	9.39	7.47	9.36	7.51	12
13	10.24	8.00	10.21	8.05	10.17	8.09	10.14	8.14	13
14	11.03	8.62	10.99	8.67	10.96	8.72	10.92	8.76	14
15	11.82	9.23	11.78	9.29	11.74	9.34	11.70	9.39	15
16	12.61	9.85	12.57	9.91	12.52	9.96	12.48	10.61	16
17	13.40	10.47	13.35	10.52	13.30	10.58	13.26	10.64	17
18	14.18	11.08	14.14	11.14	14.09	11.21	14.04	11.27	18
19	14.97	11.70	14.92	11.76	14.87	11.83	14.82	11.89	19
20	15.76	12.31	15.71	12.38	15.65	12.45	15.60	12.52	20
21	16.55	12.93	16.49	13.00	16.43	13.07	16.38	13.14	21
22	17.34	13.54	17.28	13.62	17.22	13.70	17.16	13.77	22
23	18.12	14.16	18.06	14.24	18.00	14.32	17.94	14.40	23
24	18.91	14.78	18.85	14.86	18.78	14.94	18.72	15.02	24
25	19.70	15.39	19.63	15.48	19.57	15.56	19.50	15.65	25
26	20.49	16.01	20.42	16.10	20.35	16.19	20.28	16.27	26
27	21.28	16.62	21.20	16.72	21.13	16.81	21.06	16.90	27
28	22.06	17.24	21.99	17.33	21.91	17.43	21.84	17.53	28
29	22.85	17.85	22.77	17.95	22.70	18.05	22.62	18.15	29
30	23.64	18.47	23.56	18.57	23.48	18.68	23.40	18.78	30
31	24.43	19.09	24.34	19.19	24.26	19.30	24.18	19.40	31
32	25.22	19.70	25.13	19.81	25.04	19.92	24.96	20.03	32
33	26.00	20.32	25.92	20.43	25.83	20.54	25.74	20.66	33
34	26.79	20.93	26.70	21.05	26.61	21.17	26.52	21.28	34
35	27.58	21.55	27.49	21.67	27.39	21.79	27.30	21.91	35
36	28.37	22.16	28.27	22.29	28.17	22.41	28.08	22.53	36
37	29.16	22.78	29.06	22.91	28.96	23.03	28.86	23.16	37
38	29.94	23.40	29.84	23.53	29.74	23.66	29.64	23.79	38
39	30.73	24.01	30.63	24.14	30.52	24.28	30.42	24.41	39
40	31.52	24.63	31.41	24.76	31.30	24.90	31.20	25.04	40
41	32.31	25.24	32.20	25.38	32.09	25.52	31.98	25.66	41
42	33.10	25.86	32.98	26.00	32.87	26.15	32.76	26.29	42
43	33.88	26.47	33.77	26.62	33.65	26.77	33.53	26.91	43
44	34.67	27.09	34.55	27.24	34.42	27.39	34.31	27.54	44
45	35.46	27.70	35.34	27.86	35.22	28.01	35.09	28.17	45
46	36.25	28.32	36.12	28.48	36.00	28.64	35.87	28.79	46
47	37.04	28.94	36.91	29.10	36.78	29.26	36.65	29.42	47
48	37.82	29.55	37.70	29.72	37.57	29.88	37.43	30.04	48
49	38.61	30.17	38.48	30.34	38.35	30.50	38.21	30.67	49
50	39.40	30.78	39.27	30.95	39.13	31.13	38.99	31.30	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	52 Deg.		51¾ Deg.		51½ Deg.		51¼ Deg.		

Distance	38 Deg.		38¼ Deg.		38½ Deg.		38¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	40.19	31.40	40.05	31.57	39.91	31.75	39.77	31.92	51
52	40.98	32.01	40.84	32.19	40.70	32.37	40.55	32.55	52
53	41.76	32.63	41.62	32.81	41.48	32.99	41.33	33.17	53
54	42.55	33.25	42.41	33.43	42.26	33.62	42.11	33.80	54
55	43.34	33.86	43.19	34.05	43.04	34.24	42.89	34.43	55
56	44.13	34.48	43.98	34.67	43.83	34.86	43.67	35.05	56
57	44.92	35.09	44.76	35.29	44.61	35.48	44.45	35.68	57
58	45.70	35.71	45.55	35.91	45.39	36.11	45.23	36.30	58
59	46.49	36.32	46.33	36.53	46.17	36.73	46.01	36.93	59
60	47.28	36.94	47.12	37.15	46.96	37.35	46.79	37.56	60
61	48.07	37.56	47.90	37.76	47.74	37.97	47.57	38.18	61
62	48.86	38.17	48.69	38.38	48.52	38.60	48.35	38.81	62
63	49.64	38.79	49.47	39.00	49.30	39.22	49.13	39.43	63
64	50.43	39.40	50.26	39.62	50.09	39.84	49.91	40.06	64
65	51.22	40.92	51.05	40.24	50.87	40.46	50.69	40.68	65
66	52.01	40.63	51.83	40.86	51.65	41.09	51.47	41.31	66
67	52.80	41.25	52.62	41.48	52.43	41.71	52.25	41.94	67
68	53.58	41.86	53.40	42.10	53.22	42.33	53.03	42.56	68
69	54.37	42.48	54.19	42.72	54.00	42.95	53.81	43.19	69
70	55.16	43.10	54.97	43.34	54.78	43.58	54.59	43.81	70
71	55.95	43.71	55.76	43.96	55.57	44.20	55.37	44 44	71
72	56.74	44.33	56.54	44.57	56.35	44.82	56.15	45 07	72
73	57.52	44.94	57.33	45.19	57.13	45.44	56.93	45.69	73
74	58.31	45.56	58.11	45.81	57.91	46.07	57.71	46.32	74
75	59.10	46.17	58.90	46.43	58.70	46.69	58.49	46.94	75
76	59.89	46.79	59.68	47.05	59.48	47.31	59.27	47.57	76
77	60.68	47.41	60.47	47.67	60.26	47.93	60 05	48.20	77
78	61.46	48.02	61.25	48.29	61.04	48.56	60 83	48.82	78
79	62.25	48.64	62.04	48.91	61.83	49.18	61.61	49.45	79
80	63.04	49.25	62.83	49.53	62.61	49.80	62.39	50.07	80
81	63.83	49.87	63.61	50.15	63.39	50.42	63.17	50.70	81
82	64.62	50.48	64.40	50.77	64.17	51.05	63.95	51.33	82
83	65.40	51.10	65.18	51.38	64.96	51.67	64.73	51.95	83
84	66.19	51.72	65.97	52.00	65.74	52.29	65.51	52.58	84
85	66.98	52.33	66.75	52.62	66.52	52.91	66.29	53.20	85
86	67.77	52.95	67.54	53.24	67.30	53.54	67.07	53.83	86
87	68.56	53.56	68.32	53.86	68.09	54.16	67.85	54.46	87
88	69.34	54.18	69.11	54.48	68.87	54.78	68.63	55.08	88
89	70.13	54.79	69.89	55.10	69.65	55.40	69.41	55.71	89
90	70.92	55.41	70.68	55.72	70.43	56.03	70.19	56.33	90
91	71.71	56.03	71.46	56.34	71.22	56.65	70.97	56.96	91
92	72.50	56.64	72.25	56.96	72.00	57.27	71.75	57.58	92
93	73.28	57.26	73.03	57.58	72.78	57.89	72.53	58.21	93
94	74.07	57.87	73.82	58.19	73.57	58.52	73.31	58.84	94
95	74.86	58.49	74.61	58.81	74.35	59.14	74.09	59.46	95
96	75.65	59.10	75.39	59.43	75.13	59.76	74.87	60 09	96
97	76.44	59.72	76.18	60.05	75.91	60.38	75.65	60 71	97
98	77.22	60.33	76.96	60.67	76.70	61.01	76.43	61.34	98
99	78.01	60.95	77.75	61.29	77.48	61.63	77.21	61.97	99
100	78.80	61.57	78.53	61.91	78.26	62.25	77.99	62.59	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	52 Deg.		51¾ Deg.		51½ Deg.		51¼ Deg		

Distance.	39 Deg.		39¼ Deg.		39½ Deg.		39¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.78	0.63	0.77	0.63	0.77	0.64	0.77	0 64	1
2	1.55	1.26	1.55	1.27	1.54	1.27	1.54	1.28	2
3	2.33	1.89	2.32	1.90	2.31	1.91	2.31	1.92	3
4	3.11	2.52	3.10	2.53	3.09	2.54	3.08	2.56	4
5	3.89	3.15	3.87	3.16	3.86	3.18	3.84	3.20	5
6	4.66	3.78	4.65	3.80	4.63	3.82	4.61	3.84	6
7	5.44	4.41	5.42	4.43	5.40	4.45	5.38	4.48	7
8	6.22	5.03	6.20	5.06	6.17	5.09	6.15	5.12	8
9	6.99	5.66	6.97	5.69	6.94	5.72	6.92	5.75	9
10	7.77	6.29	7.74	6.33	7.72	6.36	7.69	6.39	10
11	8.55	6.92	8.52	6.96	8.49	7.00	8.46	7.03	11
12	9.33	7.55	9.29	7.59	9.26	7.63	9.23	7.67	12
13	10.10	8.18	10.07	8.23	10.03	8.27	9.99	8.31	13
14	10.88	8.81	10.84	8.86	10.80	8.91	10.76	8.95	14
15	11.66	9.44	11.62	9.49	11.57	9.54	11.53	9.59	15
16	12.43	10.07	12.39	10.12	12.35	10.18	12.30	10.23	16
17	13.21	10.70	13.16	10.76	13.12	10.81	13.07	10.87	17
18	13.99	11.33	13.94	11.39	13.89	11.45	13.84	11.51	18
19	14.77	11.96	14.71	12.02	14 66	12.09	14.61	12.15	19
20	15.54	12.59	15.49	12.65	15.43	12.72	15.38	12.79	20
21	16.32	13.22	16.26	13.29	16.20	13.36	16.15	13.43	21
22	17.10	13.84	17.04	13.92	16.98	13.99	16.91	14.07	22
23	17.87	14.47	17.81	14.55	17.75	14.63	17.68	14.71	23
24	18.65	15.10	18.59	15.18	18.52	15.27	18.45	15.35	24
25	19.43	15.73	19.36	15.82	19.29	15.90	19.22	15.99	25
26	20.21	16.36	20.13	16.45	20.06	16.54	19.99	16.63	26
27	20.98	16.99	20.91	17.08	20.83	17.17	20.76	17.26	27
28	21.76	17.62	21.68	17.72	21.61	17.81	21.53	17.90	28
29	22.54	18.25	22.46	18.35	22.38	18.45	22.30	18.54	29
30	23.31	18.88	23.23	18.98	23.15	19.08	23.07	19.18	30
31	24.09	19.51	24.01	19.61	23.92	19.72	23.83	19.82	31
32	24.87	20.14	24.78	20.25	24.69	20.35	24.60	20.46	32
33	25.65	20.77	25.55	20.88	25.46	20.99	25.37	21.10	33
34	26.42	21.40	26.33	21.51	26.24	21.63	26.14	21.74	34
35	27.20	22.03	27.10	22.14	27.01	22.26	26.91	22.38	35
36	27.98	22.66	27.88	22.78	27.78	22.90	27.68	23.02	36
37	28.75	23.28	28.65	23.41	28.55	23.53	28.45	23.66	37
38	29.53	23.91	29.43	24.04	29.32	24.17	29.22	24.30	38
39	30.31	24.54	30.20	24.68	30.09	24.81	29.98	24.94	39
40	31.09	25.17	30.98	25.31	30.86	25.44	30.75	25.58	40
41	31.86	25.80	31.75	25.94	31.64	26.08	31.52	26.22	41
42	32.64	26.43	32.52	26.57	32.41	26.72	32.29	26.86	42
43	33.42	27.06	33.30	27.21	33.18	27.35	33.06	27.50	43
44	34.19	27.69	34.07	27.84	33.95	27.99	33.83	28.14	44
45	34.97	28.32	34.85	28.47	34.72	28.62	34.60	28.77	45
46	35.75	28.95	35.62	29.10	35.49	29.26	35.37	29.41	46
47	36.53	29.58	36.40	29.74	36.27	29.90	36.14	30.05	47
48	37.30	30.21	37.17	30.37	37.04	30.53	36.90	30.69	48
49	38.08	30.84	37.95	31.00	37.81	31.17	37.67	31.33	49
50	38.86	31.47	38.72	31.64	38.58	31.80	38.44	31.97	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	51 Deg.		50¾ Deg.		50½ Deg.		50¼ Deg.		

Distance.	39 Deg.		39¼ Deg.		39½ Deg.		39¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	39.63	32.10	39.49	32.27	39.35	32.44	39.21	32.61	51
52	40.41	32.72	40.27	32.90	40.12	33.08	39.98	33. 25	52
53	41.19	33.35	41.04	33.53	40.90	33.71	40.75	33 89	53
54	41.97	33.98	41.82	34.17	41.67	34.35	41.52	34.53	54
55	42.74	34 61	42.59	34.80	42.44	34.98	42.29	35.17	55
56	43.52	35.24	43.37	35.43	43.21	35.62	43.06	35.81	56
57	44.30	35.87	44.14	36.06	43.98	36.26	43.82	36.45	57
58	45.07	36.50	44.91	36.70	44.75	36.89	44.59	37.09	58
59	45.85	37.13	45.69	37.33	45.53	37.53	45.36	37.73	59
60	46.63	37.76	46.46	37.96	46.30	38.16	46.13	38.37	60
61	47 41	38.39	47.24	38.60	47.07	38.80	46.90	39.01	61
62	48.18	39.02	48.01	39.23	47.84	39.44	47.67	39.65	62
63	48.96	39.65	48.79	39.86	48.61	40.07	48.44	40.28	63
64	49.74	40.28	49.56	40.49	49.38	40.71	49.21	40.92	64
65	50.51	40.91	50.34	41.13	50.16	41.35	49.97	41.56	65
66	51.29	41.54	51.11	41.76	50.93	41.98	50.74	42.20	66
67	52.07	42.16	51.88	42.39	51.70	42.62	51.51	42.84	67
68	52.85	42.79	52.66	43.02	52.47	43.25	52.28	43.48	68
69	53.52	43.42	53.43	43.66	53.24	43.89	53.05	44.12	69
70	54.40	44.05	54.21	44.29	54.01	44.53	53.82	44.76	70
71	55.18	44.68	54.98	44.92	54.79	45.16	54.59	45.40	71
72	55.95	45.31	55.76	45.55	55.56	45.80	55.36	46.04	72
73	56.73	45.94	56.53	46.19	56.33	46.43	56.13	46.68	73
74	57.51	46.57	57.31	46.82	57.10	47.07	56.89	47.32	74
75	58.29	47.20	58.08	47.45	57.87	47.71	57.66	47.96	75
76	59.06	47.83	58.85	48.09	58.64	48.34	58.43	48.60	76
77	59.84	48.46	59.63	48.72	59.42	48.98	59.20	49.24	77
78	60.62	49.09	60.40	49.35	60.19	49.61	59.97	49.88	78
79	61.39	49.72	61.18	49.98	60.96	50.25	60.74	50.52	79
80	62.17	50.35	61.95	50.62	61.73	50.89	61.51	51.16	80
81	62.95	50.97	62.73	51.25	62.50	51.52	62.28	51.79	81
82	63.73	51.60	63.50	51.88	63.27	52.16	63.04	52.43	82
83	64.50	52.23	64.27	52.51	64.04	52.79	63.81	53.07	83
84	65.28	52.86	65.05	53.15	64.82	53.43	64.58	53.71	84
85	66.06	53.49	65.82	53.78	65.59	54.07	65.35	54.35	85
86	66.83	54.12	66.60	54.41	66.36	54.70	66.12	54.99	86
87	67.61	54.75	67.37	55.05	67.13	55.34	66.89	55.63	87
88	68.39	55.38	68.15	55.68	67.90	55.97	67.66	56.27	88
89	69.17	56.01	68.92	56.32	68.67	56.61	68.43	56.91	89
90	69.94	56.64	69.70	56.94	69.45	57.25	69.20	57.55	90
91	70.72	57.27	70.47	57.58	70.22	57.88	69.96	58.19	91
92	71.50	57.90	71.24	58.21	70.99	58.52	70.73	58.83	92
93	72.27	58.53	72.02	58.84	71.76	59.16	71.50	59.47	93
94	73.05	59.16	72.79	59.47	72.53	59.79	72.27	60.11	94
95	73.83	59.79	73.57	60.11	73.30	60.43	73.04	60.75	95
96	74.61	60.41	74.34	60.74	74.08	61.06	73.81	61.39	96
97	75.38	61.04	75.12	61.37	74.85	61.70	74.58	62.03	97
98	76.16	61.67	75.89	62.01	75.62	62.34	75.35	62.66	98
99	76.94	62.30	76.66	62.64	76.39	62.97	76.12	63.30	99
100	77.71	62.93	77.44	63.27	77.16	63.61	76.88	63.94	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	51 Deg.		50¾ Deg.		50½ Deg.		50¼ Deg.		

Distance.	40 Deg.		40¼ Deg.		40½ Deg.		40¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.77	0.64	0.76	0.65	0.76	0 65	0.76	0.65	1
2	1.53	1.29	1.53	1.29	1.52	1 30	1.52	1.31	2
3	2.30	1.93	2.29	1.94	2.28	1.95	2.27	1.96	3
4	3.06	2.57	3.05	2.58	3.04	2.60	3.03	2.61	4
5	3.83	3.21	3.82	3.23	3.80	3.25	3.79	3.26	5
6	4.60	3.86	4.58	3.88	4.56	3.90	4.55	3.92	6
7	5.36	4.50	5.34	4.52	5.32	4.55	5.30	4.57	7
8	6.13	5.14	6.11	5.17	6.08	5.20	6.06	5.22	8
9	6.89	5.79	6.87	5.82	6.84	5.84	6.82	5.87	9
10	7.66	6.43	7.63	6.46	7.60	6.49	7.58	6.53	10
11	8.43	7.07	8.40	7.11	8.36	7.14	8.33	7.18	11
12	9.19	7.71	9.16	7.75	9.12	7.79	9.09	7.83	12
13	9.96	8.36	9.92	8.40	9.89	8.44	9.85	8.49	13
14	10.72	9.00	10.69	9.05	10.65	9.09	10.61	9.14	14
15	11.49	9.64	11.45	9.69	11.41	9.74	11.36	9.79	15
16	12.26	10.28	12.21	10.34	12.17	10.39	12.12	10.44	16
17	13.02	10.93	12.97	10.98	12.93	11.04	12.88	11.10	17
18	13.79	11.57	13.74	11.63	13.69	11.69	13.64	11.75	18
19	14.55	12.21	14.50	12.28	14.45	12.34	14.39	12.40	19
20	15.32	12.86	15.26	12.92	15.21	12.99	15.15	13.06	20
21	16.09	13.50	16.03	13.57	15.97	13.64	15.91	13.71	21
22	16.85	14.14	16.79	14.21	16.73	14.29	16.67	14.36	22
23	17.62	14.78	17.55	14.86	17.49	14.94	17.42	15.01	23
24	18.39	15.43	18.32	15.51	18.25	15.59	18.18	15.67	24
25	19.15	16.07	19.08	16.15	19.01	16.24	18.94	16.32	25
26	19.92	16.71	19.84	16.80	19.77	16.89	19.70	16.97	26
27	20.68	17.36	20.61	17.45	20.53	17.54	20.45	17.62	27
28	21.45	18.00	21.37	18.09	21.29	18.18	21.21	18.28	28
29	22.22	18.64	22.13	18.74	22.05	18.83	21.97	18.93	29
30	22.98	19.28	22.90	19.38	22.81	19.48	22.73	19.58	30
31	23.75	19.93	23.66	20.03	23.57	20.13	23.48	20.24	31
32	24.51	20.57	24.42	20.68	24.33	20.78	24.24	20.89	32
33	25.28	21.21	25.19	21.32	25.09	21.43	25.00	21.54	33
34	26.05	21.85	25.95	21.97	25.85	22.08	25.76	22.19	34
35	26.81	22.50	26.71	22.61	26.61	22.73	26.51	22.85	35
36	27.58	23.14	27.48	23.26	27.37	23.38	27.27	23.50	36
37	28.34	23.78	28.24	23.91	28.13	24.03	28.03	24.15	37
38	29.11	24.43	29.00	24.55	28.90	24.68	28.79	24.80	38
39	29.88	25.07	29.77	25.20	29.66	25.33	29.54	25.46	39
40	30.64	25.71	30.53	25.84	30.42	25.98	30.30	26.11	40
41	31.41	26.35	31.29	26.49	31.18	26.63	31.06	26.76	41
42	32.17	27.00	32.06	27.14	31.94	27.28	31.82	27.42	42
43	32.94	27.64	32.82	27.78	32.70	27.93	32.58	28.07	43
44	33.71	28.28	33.58	28.43	33.46	28.58	33.33	28.72	44
45	34.47	28.93	34.35	29.08	34.22	29.23	34.09	29.37	45
46	35.24	29.57	35.11	29.72	34.98	29.87	34.85	30.03	46
47	36.00	30.21	35.87	30.37	35.74	30.52	35.61	30.68	47
48	36.77	30.85	36.64	31.01	36.50	31.17	36.36	31.33	48
49	37.54	31.50	37.40	31.66	37.26	31.82	37.12	31.99	49
50	38.30	32.14	38.16	32.31	38.02	32.47	37.88	32.64	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep	Lat.	Distance.
	50 Deg.		49¾ Deg.		49½ Deg.		49¼ Deg.		

Distance.	40 Deg.		40¼ Deg.		40½ Deg.		40¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	39.07	32.78	38.92	32.95	38.78	33.12	38.64	33.29	51
52	39.83	33.42	39.69	33.60	39.54	33.77	39.39	33.94	52
53	40.60	34.07	40.45	34.24	40.30	34.42	40.15	34.60	53
54	41.37	34.71	41.21	34.89	41.06	35.07	40.91	35.25	54
55	42.13	35.35	41.98	35.54	41.82	35.72	41.67	35.90	55
56	42.90	36.00	42.74	36.18	42.58	36.37	42.42	36.55	56
57	43.66	36.64	43.50	36.83	43.34	37.02	43.18	37.21	57
58	44.43	37.28	44.27	37.48	44.10	37.67	43.94	37.86	58
59	45.20	37.92	45.03	38.12	44.86	38.32	44.70	38.51	59
60	45.96	38.57	45.79	38.77	45.62	38.97	45.45	39.17	60
61	46.73	39.21	46.56	39.41	46.38	39.62	46.21	39.82	61
62	47.49	39.85	47.32	40.06	47.15	40.27	46.97	40.47	62
63	48.26	40.50	48.08	40.71	47.91	40.92	47.73	41.12	63
64	49.03	41.14	48.85	41.35	48.67	41.56	48.48	41.78	64
65	49.79	41.78	49.61	42.00	49.43	42.21	49.24	42.43	65
66	50.56	42.42	50.37	42.64	50.19	42.86	50.00	43.08	66
67	51.32	43.07	51.14	43.29	50.95	43.51	50.76	43.73	67
68	52.09	43.71	51.90	43.94	51.71	44.16	51.51	44.39	68
69	52.86	44.35	52.66	44.58	52.47	44.81	52.27	45.04	69
70	53.62	45.00	53.43	45.23	53.23	45.46	53.03	45.69	70
71	54.39	45.64	54.19	45.87	53.99	46.11	53.79	46.35	71
72	55.16	46.28	54.95	46.52	54.75	46.76	54.54	47.00	72
73	55.92	46.92	55.72	47.17	55.51	47.41	55.30	47.65	73
74	56.69	47.57	56.48	47.81	56.27	48.06	56.06	48.30	74
75	57.45	48.21	57.24	48.46	57.03	48.71	56.82	48.96	75
76	58.22	48.85	58.01	49.11	57.79	49.36	57.57	49.61	76
77	58.99	49.49	58.77	49.75	58.55	50.01	58.33	50.26	77
78	59.75	50.14	59.53	50.40	59.31	50.66	59.09	50.92	78
79	60.52	50.78	60.30	51.04	60.07	51.31	59.85	51.57	79
80	61.28	51.42	61.06	51.69	60.83	51.96	60.61	52.22	80
81	62.05	52.07	61.82	52.34	61.59	52.61	61.36	52.87	81
82	62.82	52.71	62.59	52.98	62.35	53.25	62.12	53.53	82
83	63.58	53.35	63.35	53.63	63.11	53.90	62.88	54.18	83
84	64.35	53.99	64.11	54.27	63.87	54.55	63.64	54.83	84
85	65.11	54.64	64.87	54.92	64.63	55.20	64.39	55.48	85
86	65.88	55.28	65.64	55.57	65.39	55.85	65.15	56.14	86
87	66.65	55.92	66.40	56.21	66.16	56.50	65.91	56.79	87
88	67.41	56.57	67.16	56.86	66.92	57.15	66.67	57.44	88
89	68.18	57.21	67.93	57.50	67.68	57.80	67.42	58.10	89
90	68.94	57.85	68.69	58.15	68.44	58.45	68.18	58.75	90
91	69.71	58.49	69.45	58.80	69.20	59.10	68.94	59.40	91
92	70.48	59.14	70.22	59.44	69.96	59.75	69.70	60.05	92
93	71.24	59.78	70.98	60.09	70.72	60.40	70.45	60.71	93
94	72.01	60.42	71.74	60.74	71.48	61.05	71.21	61.36	94
95	72.77	61.06	72.51	61.38	72.24	61.70	71.97	62.01	95
96	73.54	61.71	73.27	62.03	73.00	62.35	72.73	62.66	96
97	74.31	62.35	74.03	62.67	73.76	63.00	73.48	63.32	97
98	75.07	62.99	74.80	63.32	74.52	63.65	74.24	63.97	98
99	75.84	63.64	75.56	63.97	75.28	64.30	75.00	64.62	99
100	76.60	64.28	76.32	64.61	76.04	64.94	75.76	65.28	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	50 Deg.		49¾ Deg.		49½ Deg.		49¼ Deg.		

Distance.	41 Deg.		41¼ Deg.		41½ Deg.		41¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.75	0.66	0.75	0.66	0.75	0.66	0.75	0 67	1
2	1.51	1.31	1.50	1.32	1.50	1.33	1.49	1.33	2
3	2.26	1.97	2.26	1.98	2.25	1.99	2.24	2.00	3
4	3.02	2.62	3.01	2.64	3.00	2.65	2.98	2.66	4
5	3.77	3.28	3.76	3.30	3.74	3.31	3.73	3.33	5
6	4 53	3.94	4.51	3.96	4.49	3.98	4.48	4.00	6
7	5 28	4.59	5.26	4.62	5.24	4.64	5.22	4.66	7
8	6.04	5.25	6.01	5.27	5 99	5.30	5.97	5.33	8
9	6.79	5.90	6.77	5.93	6.74	5.96	6.71	5.99	9
10	7.55	6.56	7.52	6.59	7.49	6.63	7.46	6.66	10
11	8.30	7.22	8.27	7.25	8.24	7.29	8.21	7.32	11
12	9.06	7.87	9.02	7.91	8.99	7.95	8.95	7.99	12
13	9.81	8.53	9.77	8.57	9.74	8.61	9.70	8.66	13
14	10.57	9.18	10.53	9.23	10.49	9.28	10.44	9.32	14
15	11.32	9.84	11.28	9.89	11.23	9.94	11.19	9.99	15
16	12.08	10.50	12.03	10.55	11.98	10.60	11.94	10.65	16
17	12.83	11.15	12.78	11.21	12.73	11.26	12.68	11.32	17
18	13.58	11.81	13.53	11.87	13.48	11.93	13.43	11.99	18
19	14.34	12.47	14.28	12.53	14.23	12.59	14.18	12.65	19
20	15.09	13.12	15.04	13.19	14.98	13.25	14.92	13.32	20
21	15.85	13.78	15.79	13.85	15.73	13.91	15.67	13.98	21
22	16.60	14.43	16.54	14.51	16.48	14.58	16.41	14.65	22
23	17.36	15.09	17.29	15.16	17.23	15.24	17.16	15.32	23
24	18.11	15.75	18.04	15.82	17.97	15.90	17.91	15.98	24
25	18.87	16.40	18.80	16.48	18.72	16.57	18.65	16.65	25
26	19.62	17.06	19.55	17.14	19.47	17.23	19.40	17.31	26
27	20.38	17.71	20.30	17.80	20.22	17.89	20.14	17.98	27
28	21.13	18.37	21.05	18.46	20.97	18.55	20.89	18.64	28
29	21.89	19.03	21.80	19.12	21.72	19.22	21.64	19.31	29
30	22.64	19.68	22.56	19.78	22.47	19.88	22.38	19.98	30
31	23.40	20.34	23.31	20.44	23.22	20.54	23.13	20.64	31
32	24.15	20.99	24.06	21.10	23.97	21.20	23.87	21.31	32
33	24.91	21.65	24.81	21.76	24.72	21.87	24.62	21.97	33
34	25.66	22.31	25.56	22.42	25.46	22.53	25.37	22.64	34
35	26.41	22.96	26.31	23.08	26.21	23.19	26.11	23.31	35
36	27.17	23.62	27.07	23.74	26.96	23.85	26.86	23.97	36
37	27.92	24.27	27.82	24.40	27.71	24.52	27.60	24.64	37
38	28.68	24.93	28.57	25.06	28.46	25.18	28.35	25.30	38
39	29.43	25.59	29.32	25.71	29.21	25.84	29.10	25.97	39
40	30.19	26.24	30.07	26.37	29.96	26.50	29.84	26.64	40
41	30.94	26.90	30.83	27.03	30.71	27.17	30.59	27.30	41
42	31.70	27.55	31.58	27.69	31.46	27.83	31.33	27.97	42
43	32.45	28.21	32.33	28.35	32.21	28.49	32.08	28.63	43
44	33.21	28.87	33.08	29.01	32.95	29.16	32.83	29.30	44
45	33.96	29.52	33.83	29.67	33.70	29.82	33.57	29.97	45
46	34.72	30.18	34.58	30.33	34.45	30.48	34.32	30.63	46
47	35.47	30.83	35.34	30.99	35.20	31.14	35.06	31.30	47
48	36.23	31.49	36.09	31.65	35.95	31.81	35.81	31 96	48
49	36.98	32.15	36.84	32.31	36.70	32.47	36.56	32.63	49
50	37.74	32.80	37.59	32.97	37.45	33.13	37.20	33.29	50
Distance.	Dep.	Lat.	Dep	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	49 Deg.		48¾ Deg.		48½ Deg.		48¼ Deg.		

Distance.	41 Deg.		41¼ Deg.		41½ Deg.		41¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	38.49	33.46	38.34	33.63	38.20	33.79	38.05	33.96	51
52	39.24	34.12	39.10	34.29	38.95	34.46	38.79	34.63	52
53	40.00	34.77	39.85	34.95	39.69	35.12	39.54	35.29	53
54	40.75	35.43	40.60	35.60	40.44	35.78	40.29	35.96	54
55	41.51	36.08	41.35	36.26	41.19	36.44	41.03	36.62	55
56	42.26	36.74	42.10	36.92	41.94	37.11	41.78	37.29	56
57	43.02	37.40	42.85	37.58	42.69	37.77	42.53	37.96	57
58	43.77	38.05	43.61	38.24	43.44	38.43	43.27	38.62	58
59	44.53	38.71	44.36	38.90	44.19	39.09	44.02	39.29	59
60	45.28	39.36	45.11	39.56	44.94	39.76	44.76	39.95	60
61	46.04	40.02	45.86	40.22	45.69	40.42	45.51	40.62	61
62	46.79	40.68	46.61	40.88	46.44	41.08	46.26	41.28	62
63	47.55	41.33	47.37	41.54	47.18	41.75	47.00	41.95	63
64	48.30	41.99	48.12	42.20	47.93	42.41	47.75	42.62	64
65	49.06	42.64	48.87	42.86	48.68	43.07	48.49	43.28	65
66	49.81	43.30	49.62	43.52	49.43	43.73	49.24	43.95	66
67	50.57	43.96	50.37	44.18	50.18	44.40	49.99	44.61	67
68	51.32	44.61	51.13	44.84	50.93	45.06	50.73	45.28	68
69	52.07	45.27	51.88	45.49	51.68	45.72	51.48	45.95	69
70	52.83	45.92	52.63	46.15	52.43	46.38	52.22	46.61	70
71	53.58	46.58	53.38	46.81	53.18	47.05	52.97	47.28	71
72	54.34	47.24	54.13	47.47	53.92	47.71	53.72	47.94	72
73	55.09	47.89	54.88	48.13	54.67	48.37	54.46	48.61	73
74	55.85	48.55	55.64	48.79	55.42	49.03	55.21	49.28	74
75	56.60	49.20	56.39	49.45	56.17	49.70	55.95	49.94	75
76	57.36	49.86	57.14	50.11	56.92	50.36	56.70	50.61	76
77	58.11	50.52	57.89	50.77	57.67	51.02	57.45	51.27	77
78	58.87	51.17	58.64	51.43	58.42	51.68	58.19	51.94	78
79	59.62	51.83	59.40	52.09	59.17	52.35	58.94	52.60	79
80	60.38	52.48	60.15	52.75	59.92	53.01	59.68	53.27	80
81	61.13	53.14	60.90	53.41	60.67	53.67	60.43	53.94	81
82	61.89	53.80	61.65	54.07	61.41	54.33	61.18	54.60	82
83	62.64	54.45	62.40	54.73	62.16	55.00	61.92	55.27	83
84	63.40	55.11	63.15	55.38	62.91	55.66	62.67	55.93	84
85	64.15	55.76	63.91	56.04	63.66	56.32	63.41	56.60	85
86	64.90	56.42	64.66	56.79	64.41	56.99	64.16	57.27	86
87	65.66	57.08	65.41	57.36	65.16	57.65	64.91	57.93	87
88	66.41	57.73	66.16	58.02	65.91	58.31	65.65	58.60	88
89	67.17	58.39	66.91	58.68	66.66	58.97	66.40	59.26	89
90	67.92	59.05	67.67	59.34	67.41	59.64	67.15	59.93	90
91	68.68	59.70	68.42	60.00	68.15	60.30	67.89	60.60	91
92	69.43	60.36	69.17	60.66	68.90	60.96	68.64	61.26	92
93	70.19	61.01	69.92	61.32	69.65	61.62	69.38	61.93	93
94	70.94	61.67	70.67	61.98	70.40	62.29	70.13	62.59	94
95	71.70	62.33	71.43	62.64	71.15	62.95	70.88	63.26	95
96	72.45	62.98	72.18	63.30	71.90	63.61	71.62	63.92	96
97	73.21	63.64	72.93	63.96	72.65	64.27	72.37	64.59	97
98	73.96	64.29	73.68	64.62	73.40	64.94	73.11	65.26	98
99	74.72	64.95	74.43	65.28	74.15	65.60	73.86	65.92	99
100	75.47	65.61	75.18	65.93	74.90	66.26	74.61	66.59	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	49 Deg.		48¾ Deg.		48½ Deg.		48¼ Deg.		

Distance.	42 Deg.		42¼ Deg.		42½ Deg.		42¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.74	0.67	0.74	0.67	0.74	0.68	0.73	0.68	1
2	1.49	1.34	1.48	1.34	1.47	1.35	1.47	1.36	2
3	2.23	2.01	2.22	2.02	2.21	2.03	2.20	2.04	3
4	2.97	2.68	2.96	2.69	2.95	2.70	2.94	2.72	4
5	3.72	3.35	3.70	3.36	3.69	3.38	3.67	3.39	5
6	4.46	4.01	4.44	4.03	4.42	4.05	4.41	4.07	6
7	5.20	4.68	5.18	4.71	5.16	4.73	5.14	4.75	7
8	5.95	5.35	5.92	5.38	5.90	5.40	5.87	5.43	8
9	6.69	6.02	6.66	6.05	6.64	6.08	6.61	6.11	9
10	7.43	6.69	7.40	6.72	7.37	6.76	7.34	6.79	10
11	8.17	7.36	8.14	7.40	8.11	7.43	8.08	7.47	11
12	8.92	8.03	8.88	8.07	8.85	8.11	8.81	8.15	12
13	9.66	8.70	9.62	8.74	9.58	8.78	9.55	8.82	13
14	10.40	9.37	10.36	9.41	10.32	9.46	10.28	9.50	14
15	11.15	10.04	11.10	10.09	11.06	10.13	11.01	10.18	15
16	11.89	10.71	11.84	10.76	11.80	10.81	11.75	10.86	16
17	12.63	11.38	12.58	11.43	12.53	11.48	12.48	11.54	17
18	13.38	12.04	13.32	12.10	13.27	12.16	13.22	12.22	18
19	14.12	12.71	14.06	12.77	14.01	12.84	13.95	12.90	19
20	14.86	13.38	14.80	13.45	14.75	13.51	14.69	13.58	20
21	15.61	14.05	15.54	14.12	15.48	14.19	15.42	14.25	21
22	16.35	14.72	16.28	14.79	16.22	14.86	16.16	14.93	22
23	17.09	15.39	17.02	15.46	16.96	15.54	16.89	15.61	23
24	17.84	16.06	17.77	16.14	17.69	16.21	17.62	16.29	24
25	18.58	16.73	18.51	16.81	18.43	16.89	18.36	16.97	25
26	19.32	17.40	19.25	17.48	19.17	17.57	19.09	17.65	26
27	20.06	18.07	19.99	18.15	19.91	18.24	19.83	18.33	27
28	20.81	18.74	20.73	18.83	20.64	18.92	20.56	19.01	28
29	21.55	19.40	21.47	19.50	21.38	19.59	21.30	19.69	29
30	22.29	20.07	22.21	20.17	22.12	20.27	22.03	20.36	30
31	23.04	20.74	22.95	20.84	22.86	20.94	22.76	21.04	31
32	23.78	21.41	23.69	21.52	23.59	21.62	23.50	21.72	32
33	24.52	22.08	24.43	22.19	24.33	22.29	24.23	22.40	33
34	25.27	22.75	25.17	22.86	25.07	22.97	24.97	23.08	34
35	26.01	23.42	25.5.	23.53	25.80	23.65	25.70	23.76	35
36	26.75	24.09	26.65	24.21	26.54	24.32	26.44	24.44	36
37	27 50	24.76	27.39	24.88	27.28	25.00	27.17	25.12	37
38	28.24	25.43	28.13	25.55	28.02	25.67	27.90	25.79	38
39	28.98	26.10	28.87	26.22	28.75	26.35	28.64	26.47	39
40	29.73	26.77	29.61	26.89	29.49	27.02	29.37	27.15	40
41	30.47	27.43	30.35	27.57	30.23	27.70	30.11	27.83	41
42	31.21	28.10	31.09	28.24	30.97	28.37	30.84	28.51	42
43	31.96	28.77	31.83	28.91	31.79	29.05	31.58	29.19	43
44	32.70	29.44	32.57	29.58	32.44	29.73	32.31	29 87	44
45	33.44	30.11	33.31	30.26	33.18	30.40	33.04	30.55	45
46	34.18	30.78	34.05	30.93	33.91	31.08	33.78	31.22	46
47	34.93	31.45	34.79	31.60	24.65	31.75	34.51	31.90	47
48	35.67	32.12	35.53	32.27	35.39	32.43	35.25	32.58	48
49	36.41	32.79	36.27	32.95	36.13	33.10	35.98	33.26	49
50	37.16	33.46	37.01	33.62	36.86	33.78	36.72	33.94	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat	Distance.
	48 Deg.		47¾ Deg.		47½ Deg.		47¼ Deg.		

Distance.	42 Deg.		42¼ Deg.		42½ Deg.		42¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	37.90	34.13	37.75	34.29	37.60	34.46	37.45	34.62	51
52	38.64	34.79	38.49	34.96	38.34	35.13	38.18	35.30	52
53	39.39	35.46	39.23	35.64	39.08	35.81	38.92	35.98	53
54	40.13	36.13	39.97	36.31	39.81	36.48	39.65	36.66	54
55	40.87	36.80	40.71	36.98	40.55	37.16	40.39	37.33	55
56	41.62	37.47	41.45	37.65	41.29	37.83	41.12	38.01	56
57	42.36	38.14	42.19	38.32	42.02	38.51	41.86	38.69	57
58	43.10	38.81	42.93	39.00	42.76	39.18	42.59	39.37	58
59	43.85	39.48	43.67	39.67	43.50	39.86	43.32	40.05	59
60	44.59	40.15	44.41	40.34	44.24	40.54	44.06	40.73	60
61	45.33	40.82	45.15	41.01	44.97	41.21	44.79	41.41	61
62	46.07	41.49	45.89	41.69	45.71	41.89	45.53	42.09	62
63	46.82	42.16	46.63	42.36	46.45	42.56	46.26	42.76	63
64	47.56	42.82	47.37	43.03	47.19	43.24	47.00	43.44	64
65	48.30	43.49	48.11	43.70	47.92	43.91	47.73	44.12	65
66	49.05	44.16	48.85	44.38	48.66	44.59	48.47	44.80	66
67	49.79	44.83	49.59	45.05	49.40	45.26	49.20	45.48	67
68	50.53	45.50	50.33	45.72	50.13	45.94	49.93	46.16	68
69	51.28	46.17	51.07	46.39	50.87	46.62	50.67	46.84	69
70	52.02	46.84	51.82	47.07	51.61	47.29	51.40	47.52	70
71	52.76	47.51	52.56	47.74	52.35	47.97	52.14	48.19	71
72	53.51	48.18	53.30	48.41	53.08	48.64	52.87	48.87	72
73	54.25	48.85	54.04	49.08	53.82	49.22	53.61	49.55	73
74	54.99	49.52	54.78	49.76	54.56	49.99	54.34	50.23	74
75	55.74	50.18	55.52	50.43	55.30	50.67	55.07	50.91	75
76	56.48	50.85	56.26	51.10	56.03	51.34	55.81	51.59	76
77	57.22	51.52	57.00	51.77	56.77	52.02	56.54	52.27	77
78	57.97	52.19	57.74	52.44	57.51	52.70	57.28	52.95	78
79	58.71	52.86	58.48	53.12	58.24	53.37	58.01	53.63	79
80	59.45	53.53	59.22	53.79	58.98	54.05	58.75	54.30	80
81	60.19	54.20	59.96	54.46	59.72	54.72	59.48	54.98	81
82	60.94	54.87	60.70	55.13	60.46	55.40	60.21	55.66	82
83	61.68	55.54	61.44	55.81	61.19	56.07	60.95	56.34	83
84	62.42	56.21	62.18	56.48	61.93	56.75	61.68	57.02	84
85	63.17	56.88	62.92	57.15	62.67	57.43	62.42	57.70	85
86	63.91	57.55	63.66	57.82	63.41	58.10	63.15	58.38	86
87	64.65	58.21	64.40	58.50	64.14	58.78	63.89	59.06	87
88	65.40	58.88	65.14	59.17	64.88	59.45	64.62	59.73	88
89	66.14	59.55	65.88	59.84	65.62	60.13	65.35	60.41	89
90	66.88	60.22	66.62	60.51	66.35	60.80	66.09	61.09	90
91	67.63	60.89	67.36	61.19	67.09	61.48	66.82	61.77	91
92	68.37	61.56	68.10	61.86	67.83	62.15	67.56	62.45	92
93	69.11	62.23	68.84	62.53	68.57	62.83	68.29	63.13	93
94	69.86	62.90	69.58	63.20	69.30	63.51	69.03	63.81	94
95	70.60	63.57	70.32	63.87	70.04	64.18	69.76	64.49	95
96	71.34	64.24	71.06	64.55	70.78	64.86	70.49	65.16	96
97	72.08	64.91	71.80	65.22	71.52	65.53	71.23	65.84	97
98	72.83	65.57	72.54	65.89	72.25	66.21	71.96	66.52	98
99	73.57	66.24	73.28	66.56	72.99	66.88	72.70	67.20	99
100	74.31	66.91	74.02	67.24	73.73	67.56	73.43	67.88	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	48 Deg.		47¾ Deg.		47½ Deg		47¼ Deg.		

Distance.	43 Deg.		43¼ Deg.		43½ Deg.		43¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.73	0.68	0.73	0.69	0.73	0.69	0.72	0.69	1
2	1.46	1.36	1.46	1.37	1.45	1.38	1.44	1.38	2
3	2.19	2.05	2.19	2.06	2.18	2.07	2.17	2.07	3
4	2.93	2.73	2.91	2.74	2.90	2.75	2.89	2.77	4
5	3.66	3.41	3.64	3.43	3.63	3.44	3.61	3.46	5
6	4.39	4.09	4.37	4.11	4.35	4.13	4.33	4.15	6
7	5.12	4.77	5.10	4.80	5.08	4.82	5.06	4.84	7
8	5.85	5.46	5.83	5.48	5.80	5.51	5.78	5.53	8
9	6.58	6.14	6.56	6.17	6.53	6.20	6.50	6.22	9
10	7.31	6.82	7.28	6.85	7.25	6.88	7.22	6.92	10
11	8.04	7.50	8.01	7.54	7.98	7.57	7.95	7.61	11
12	8.78	8.18	8.74	8.22	8.70	8.26	8.67	8.30	12
13	9.51	8.87	9.47	8.91	9.43	8.95	9.39	8.99	13
14	10.24	9.55	10.20	9.59	10.16	9.64	10.11	9.68	14
15	10.97	10.23	10.93	10.28	10.88	10.33	10.84	10.37	15
16	11.70	10.91	11.65	10.96	11.61	11.01	11.56	11.06	16
17	12.43	11.59	12.38	11.65	12.33	11.70	12.28	11.76	17
18	13.16	12.28	13.11	12.33	13.06	12.39	13.00	12.45	18
19	13.90	12.96	13.84	13.02	13.78	13.08	13.72	13.14	19
20	14.63	13.64	14.57	13.70	14.51	13.77	14.45	13.83	20
21	15.36	14.32	15.30	14.39	15.23	14.46	15.17	14.52	21
22	16.09	15.00	13.02	15.07	15.96	15.14	15.89	15.21	22
23	16.82	15.69	16.75	15.76	16.68	15.83	16.61	15.90	23
24	17.55	16.37	17.48	16.44	17.41	16.52	17.34	16.60	24
25	18.28	17.05	18.21	17.13	18.13	17.21	18.06	17.29	25
26	19.02	17.73	18.94	17.81	18.86	17.90	18.78	17.98	26
27	19.75	18.41	19.67	18.50	19.59	18.59	19.50	18.67	27
28	20.48	19.10	20.39	19.19	20.31	19.27	20.23	19.36	28
29	21.21	19.78	21.12	19.87	21.04	19.96	20.95	20.05	29
30	21.94	20.46	21.85	20.56	21.76	20.65	21.67	20.75	30
31	22.67	21.14	22.58	21.24	22.49	21.34	22.39	21.44	31
32	23.40	21.82	23.31	21.93	23.21	22.03	23.12	22.13	32
33	24.13	22.51	24.04	22.61	23.94	22.72	23.84	22.82	33
34	24.87	23.19	24.76	23.30	24.66	23.40	24.56	23.51	34
35	25.60	23.87	25.49	23.98	25.39	24.09	25.28	24.20	35
36	26.33	24.55	26.22	24.67	26.11	24.78	26.01	24.89	36
37	27.06	25.23	26.95	25.35	26.84	25.47	26.73	25.59	37
38	27.79	25.92	27.68	26.04	27.56	26.16	27.45	26.28	38
39	28.52	26.60	28.41	26.72	28.29	26.85	28.17	26.97	39
40	29.25	27.28	29.13	27.41	29.01	27.53	28.89	27.66	40
41	29.99	27.96	29.86	28.09	29.74	28.22	29.62	28.35	41
42	30.72	28.64	30.59	28.78	30.47	28.91	30.34	29.04	42
43	31.45	29.33	31.32	29.46	31.19	29.60	31.06	29.74	43
44	32.18	30.01	32.05	30.15	31.92	30.29	31.78	30.43	44
45	32.91	30.69	32.78	30.83	32.64	30.98	32.51	31.12	45
46	33.64	31.37	33.51	31.52	33.37	31.66	33.23	31.81	46
47	34.37	32.05	34.23	32.20	34.09	32.35	33.95	32.50	47
48	35.10	32.74	34.96	32.89	34.82	33.04	34.67	32.19	48
49	35.84	33.42	35.69	33.57	35.54	33.73	35.40	33.88	49
50	36.57	34.10	36.42	34.26	36.27	34.42	36.12	34.58	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	47 Deg.		46¾ Deg.		46½ Deg.		46¼ Deg		

Distance.	43 Deg.		43¼ Deg.		43½ Deg.		43¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	37.30	34.78	37.15	34.94	36.99	35.11	36.84	35.27	51
52	38.03	35.46	37.88	35.63	37.72	35.79	37.56	35.96	52
53	38.76	36.15	38.60	36.31	38.44	36.48	38.29	36.65	53
54	39.49	36.83	39.33	37.00	39.17	37.17	39.01	37.34	54
55	40.22	37.51	40.06	37.69	39.90	37.86	39.73	38.03	55
56	40.96	38.19	40.79	38.37	40.62	38.55	40.45	38.72	56
57	41.69	38.87	41.52	39.06	41.35	39.24	41.17	39.42	57
58	42.42	39.56	42.25	39.74	42.07	39.92	41.90	40.11	58
59	43.15	40.24	42.97	40.43	42.80	40.61	42.62	40.80	59
60	43.88	40.92	43.70	41.11	43.52	41.30	43.34	41.49	60
61	44.61	41.60	44.43	41.80	44.25	41.99	44.06	42.18	61
62	45.34	42.28	45.16	42.48	44.97	42.68	44.79	42.87	62
63	46.08	42.97	45.89	43.17	45.70	43.37	45.51	43.57	63
64	46.81	43.65	46.62	43.85	46.42	44.05	46.23	44.26	64
65	47.54	44.33	47.34	44.54	47.15	44.74	46.95	44.95	65
66	48.27	45.01	48.07	45.22	47.87	45.43	47.68	45.64	66
67	49.00	45.69	48.80	45.91	48.60	46.12	48.40	46.33	67
68	49.73	46.38	49.53	46.59	49.33	46.81	49.12	47.02	68
69	50.46	47.06	50.26	47.28	50.05	47.50	49.84	47.71	69
70	51.19	47.74	50.99	47.96	50.78	48.18	50.57	48.41	70
71	51.93	48.42	51.71	48.65	51.50	48.87	51.29	49.10	71
72	52.66	49.10	52.44	49.33	52.23	49.56	52.01	49.79	72
73	53.39	49.79	53.17	50.02	52.95	50.25	52.73	50.48	73
74	54.12	50.47	53.90	50.70	53.68	50.94	53.45	51.17	74
75	54.85	51.15	54.63	51.39	54.40	51.63	54.18	51.86	75
76	55.58	51.83	55.36	52.07	55.13	52.31	54.90	52.55	76
77	56.31	52.51	56.08	52.76	55.85	53.00	55.62	53.25	77
78	57.05	53.20	56.81	53.44	56.58	53.69	56.34	53.94	78
79	57.78	53.88	57.54	54.13	57.30	54.38	57.07	54 63	79
80	58.51	54.56	58.27	54.81	58.03	55.07	57.79	55.32	80
81	59.24	55.24	59.00	55.50	58.76	55.76	58.51	56.01	81
82	59.97	55.92	59.73	56.18	59.48	56.45	59.23	56.70	82
83	60.70	56.61	60.45	56.87	60.21	57.13	59.96	57.40	83
84	61.43	57.29	61.18	57.56	60.93	57.82	60.68	58.09	84
85	62.17	57.97	61.91	58.24	61.66	58.51	61.40	58.78	85
86	62.90	58.65	62.64	58.93	62.38	59.20	62.12	59.47	86
87	63.63	59.33	63.37	59.61	63.11	59.89	62.85	60.16	87
88	64.36	60.02	64.10	60.30	63.83	60.58	63.57	60.85	88
89	65.09	60.70	64.82	60.98	64.56	61.26	64.29	61.54	89
90	65.82	61.38	65.55	61.67	65.28	61.95	65.01	62.24	90
91	66.55	62.06	66.28	62.35	66.01	62.64	65.74	62.93	91
92	67.28	62.74	67.01	63.04	66.73	63.33	66.46	63.62	92
93	68.02	63.43	67.74	63.72	67.46	64.02	67.18	64.31	93
94	68.75	64.11	68.47	64.41	68.19	64.71	67.90	65.00	94
95	69.48	64.79	69.20	65.09	68.91	65.39	68.62	65.69	95
96	70.21	65.47	69.92	65.78	69.64	66.08	69.35	66.39	96
97	70.94	66.15	70.65	66.46	70.36	66.77	70.07	67.08	97
98	71.67	66.84	71.37	67 15	71.09	67.46	70.79	67.77	98
99	72.40	67.52	72.11	67.83	71.81	68.15	71.51	68.46	99
100	73.14	68.20	72.84	68.52	72.54	68.84	72.24	69.15	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	47 Deg.		46¾ Deg.		46½ Deg.		46¼ Deg.		

Distance.	44 Deg.		44¼ Deg.		44½ Deg.		44¾ Deg.		45 Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0.72	0.69	0.72	0.70	0.71	0.70	0.71	0.71	0.71	0.71	1
2	1.44	1.39	1.43	1.40	1.43	1.40	1.42	1.41	1.41	1.41	2
3	2.16	2.08	2.15	2.09	2.14	2.10	2.13	2.11	2.12	2.12	3
4	2.88	2.78	2.87	2.79	2.85	2.80	2.84	2.82	2.83	2.83	4
5	3.60	3.47	3.58	3.49	3.57	3.50	3.55	3.52	3.54	3.54	5
6	4.32	4.17	4.30	4.19	4.28	4.21	4.26	4.22	4.24	4.24	6
7	5.04	4.86	5.01	4.88	4.99	4.91	4.97	4.93	4.95	4.95	7
8	5.75	5.56	5.73	5.58	5.71	5.61	5.68	5.63	5.66	5.66	8
9	6.47	6.25	6.45	6.28	6.42	6.31	6.39	6.34	6.36	6.36	9
10	7.19	6.95	7.16	6.98	7.13	7.01	7.10	7.04	7.07	7.07	10
11	7.91	7.64	7.88	7.68	7.85	7.71	7.81	7.74	7.78	7.78	11
12	8.63	8.34	8.60	8.37	8.56	8.41	8.52	8.45	8.49	8.49	12
13	9.35	9.03	9.31	9.07	9.27	9.11	9.23	9.15	9.19	9.19	13
14	10.07	9.73	10.03	9.77	9.99	9.81	9.94	9.86	9.90	9.90	14
15	10.79	10.42	10.74	10.47	10.70	10.51	10.65	10.56	10.61	10.61	15
16	11.51	11.11	11.46	11.16	11.41	11.21	11.36	11.26	11.31	11.31	16
17	12.23	11.81	12.18	11.86	12.13	11.92	12.07	11.97	12.02	12.02	17
18	12.95	12.50	12.89	12.56	12.84	12.62	12.78	12.67	12.73	12.73	18
19	13.67	13.20	13.61	13.26	13.55	13.32	13.49	13.38	13.43	13.43	19
20	14.39	13.89	14.33	13.96	14.26	14.02	14.20	14.08	14.14	14.14	20
21	15.11	14.59	15.04	14.65	14.98	14.72	14.91	14.78	14.85	14.85	21
22	15.83	15.28	15.76	15.35	15.69	15.42	15.62	15.49	15.56	15.56	22
23	16.54	15.98	16.47	16.05	16.40	16.12	16.33	16.19	16.26	16.26	23
24	17.26	16.67	17.19	16.75	17.12	16.82	17.04	16.90	16.97	16.97	24
25	17.98	17.37	17.91	17.44	17.83	17.52	17.75	17.60	17.68	17.68	25
26	18.70	18.06	18.62	18.14	18.54	18.22	18.46	18.30	18.38	18.38	26
27	19.42	18.76	19.34	18.84	19.26	18.92	19.17	19.01	19.09	19.09	27
28	20.14	19.45	20.06	19.54	19.97	19.63	19.89	19.71	19.80	19.80	28
29	20.86	20.15	20.77	20.24	20.68	20.33	20.60	20.42	20.51	20.51	29
30	21.58	20.84	21.49	20.93	21.40	21.03	21.31	21.12	21.21	21.21	30
31	22.30	21.53	22.21	21.63	22.11	21.73	22.02	21.82	21.92	21.92	31
32	23.02	22.23	22.92	22.33	22.82	22.43	22.73	22.53	22.63	22.63	32
33	23.74	22.92	23.64	23.03	23.54	23.13	23.44	23.23	23.33	23.33	33
34	24.46	23.62	24.35	23.72	24.25	23.83	24.15	23.94	24.04	24.04	34
35	25.18	24.31	25.07	24.42	24.96	24.53	24.86	24.64	24.75	24.75	35
36	25.90	25.01	25.79	25.12	25.68	25.23	25.57	25.34	25.46	25.46	36
37	26.62	25.70	26.50	25.82	26.39	25.93	26.28	26.05	26.16	26.16	37
38	27.33	26.40	27.22	26.52	27.10	26.63	26.99	26.75	26.87	26.87	38
39	28.05	27.09	27.94	27.21	27.82	27.34	27.70	27.46	27.58	27.58	39
40	28.77	27.79	28.65	27.91	28.53	28.04	28.41	28.16	28.28	28.28	40
41	29.49	28.48	29.37	28.61	29.24	28.74	29.12	28.86	28.99	28.99	41
42	30.21	29.18	30.08	29.31	29.96	29.44	29.83	29.57	29.70	29.70	42
43	30.93	29.87	30.80	30.00	30.67	30.14	30.54	30.27	30.41	30.41	43
44	31.65	30.56	31.52	30.70	31.38	30.84	31.25	30.98	31.11	31.11	44
45	32.37	31.26	32.23	31.40	32.10	31.54	31.96	31.68	31.82	31.82	45
46	33.09	31.95	32.95	32.10	32.81	32.24	32.67	32.38	32.53	32.53	46
47	33.81	32.65	33.67	32.80	33.52	32.94	33.38	33.09	33.23	33.23	47
48	34.53	33.34	34.38	33.49	34.24	33.64	34.09	33.79	33.94	33.94	48
49	35.25	34.04	35.10	34.19	34.95	34.34	34.30	24.50	34.65	34.65	49
50	35.97	34.73	35.82	34.89	35.66	35.05	35.51	35.20	35.36	35.36	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	46 Deg		45¾ Deg.		45½ Deg.		45¼ Deg.		45 Deg.		

Distance.	44 Deg.		44¼ Deg.		44½ Deg.		44¾ Deg.		45 Deg.		Distance.
	Lat	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	36.69	35.43	36 53	35.59	36.38	35.75	36.22	35.90	36.06	36.06	51
52	37.41	36.12	37.25	36.29	37.09	36.45	36.93	36.61	36.77	36.77	52
53	38.12	36.82	37.96	36.98	37.80	37.15	37.64	37.31	37.48	37.48	53
54	38.84	37.51	38.68	37.68	38.52	37.85	38 35	38.02	38.18	38.18	54
55	39.56	38.21	39.40	38.38	39.23	38.55	39.06	38.72	38.89	38.89	55
56	40.28	38.90	40.11	39.08	39.94	39.25	39.77	39.42	39.60	39.60	56
57	41.00	39.60	40.83	39.77	40.66	39.95	40.48	40.13	40.31	40.31	57
58	41.72	40.29	41.55	40.47	41.37	40.65	41.19	40.83	41.01	41.01	58
59	42.44	40.98	42.26	41.17	42.08	41.35	41.90	41.54	41.72	41.72	59
60	43.16	41.68	42.98	41.87	42.79	42.05	42.61	42.24	42.43	42.43	60
61	43.88	42.37	43.69	42.57	43.51	42.76	43.32	42.94	43.13	43.13	61
62	44.60	43.07	44.41	43.26	44.22	43.46	44.03	43.65	43.84	43.84	62
63	45.32	43.76	45.13	43.96	44.93	44.16	44.74	44.35	44.55	44.55	63
64	46.04	44.46	45.84	44.66	45.65	44.86	45.45	45.06	45.25	45.25	64
65	46.76	45.15	46.56	45.36	46 36	45.56	46.16	45.76	45.96	45.96	65
66	47.48	45.85	47.28	46.05	47.07	46.26	46.87	46.46	46.67	46.67	66
67	48.20	46.54	47.99	46.75	47.79	46.96	47.58	47.17	47.38	47.38	67
68	48.92	47.24	48.71	47.45	48.50	47.66	48.29	47.87	48.08	48.08	68
69	49.63	47.93	49.42	48.15	49.21	48.36	49.00	48.58	48.79	48.79	69
70	50.35	48.63	50.14	48.85	49.93	49.06	49.71	49.28	49.50	49.50	70
71	51.07	49.32	50.86	49.54	50.64	49.76	50.42	49.98	50.20	50.20	71
72	51.79	50.02	51.57	50.24	51.35	50.47	51.13	50.69	50.91	50.91	72
73	52.51	50.71	52.29	50.94	52.07	51.17	51.84	51.39	51.62	51.62	73
74	53.23	51.40	53.01	51.64	52.78	51.87	52.55	52.10	52.33	52.33	74
75	53.95	52.10	53.72	52.33	53.49	52.57	53.26	52.80	53.03	53.03	75
76	54 67	52.79	54.44	53.03	54.21	53.27	53.97	53.51	53.74	53.74	76
77	55.39	53.49	55.16	53.73	54.92	53.97	54.68	54.21	54.45	54.45	77
78	56.11	54.18	55.87	54.43	55.63	54.67	55.39	54.91	55.15	55.15	78
79	56.83	54.88	56.59	55.13	56.35	55.37	56.10	55.62	55.86	55.86	79
80	57.55	55.57	57.30	55.82	57.06	56.07	56.81	56.32	56.57	56.57	80
81	58.27	56.27	58.02	56.52	57.77	56.77	57.52	57.03	57.28	57.28	81
82	58.99	56.96	58.74	57.22	58.49	57.47	58.24	57.73	57.98	57.98	82
83	59.71	57.66	59.45	57.92	59.20	58.18	58.95	58.43	58.69	58.69	83
84	60.42	58.35	60.17	58.61	59.91	58.88	59.66	59.14	59.40	59.40	84
85	61.14	59.05	60.89	59.31	60.63	59.58	60.37	59.84	60.10	60.10	85
86	61.86	59 74	61.60	60.01	61.34	60.28	61.08	60.55	66.81	60.81	86
87	62.58	60.44	62.32	60.71	62.05	60.98	61.79	61.25	61.52	61.52	87
88	63.30	61.13	63.03	61.41	62.77	61.68	62.50	61.95	62.23	62.23	88
89	64.02	61.82	63.75	62.10	63.48	62.38	63.21	62.66	62.93	62.93	89
90	64.74	62.52	64.47	62.80	64.19	63.08	63.92	63.36	63.64	63 64	90
91	65.46	63.21	65.18	63.50	64.91	63.78	64.63	64.07	64.35	64.35	91
92	66.18	63.91	65.90	64.20	65.62	64.48	65.34	64.77	65.05	65.05	92
93	66.90	64.60	66.62	64.89	66.33	65.18	66.05	65.47	65.76	65.76	93
94	67.62	65.30	67.33	65.59	67.05	65.89	66.76	66.18	66.47	66.47	94
95	68.34	65.99	68.05	66.29	67.76	66.59	67.47	66.88	67.18	67.18	95
96	69.06	66.69	68.76	66.99	68.47	67.29	68.18	67.59	67.88	67.88	96
97	69.78	67.38	69.48	67.69	69.19	67.99	68.89	68.29	68.59	68.59	97
98	70.50	68.08	70.20	68.38	69.90	68 69	69.60	68.99	69.30	69.30	98
99	71.21	68.77	70.91	69.08	70.61	69.39	70.31	69.70	70.00	70.00	99
100	71 93	69.47	71.63	69.78	71.33	70.09	71.02	70.40	70.71	70.71	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep	Lat.	Distance.
	46 Deg.		45¾ Deg.		45½ Deg.		45¼ Deg.		45 Deg.		

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